ACTA ORTHOPAEDICA SCANDINAVICA

VOL. XXXV

# ACTA ORTHOPAEDICA SCANDINAVICA



VOL XXXV — FASC 1–4

MUNKSGAARD COPENHAGEN 1965

Munksgaard
International Booksellers and Publishers Ltd
47 Prags Boulevard Copenhagen S Denmark





PRINTED IN DENMARK
VALD PEDERSENS BOGTRYKKERI
COPENHAGEN

Acta orthop Scandinav XXXI 1-15 1964

From the Department of Orthopaedics and the Laboratory of Clinical Neurophysiology Sahlgrenska sjukhuset Goteborg Sweden
and the Kaiser Laboratory Copenhagen Denmark

# BIOELECTRICAL CONTROL IN A SERVO SYSTEM

## *Analysis and Application of Muscle Action Potentials in an Experimental Hand Prosthesis*

*By*

C Hirsch E Kaiser and I Petersen

By incorporating a motor and source of current into a hand prosthesis a system can be created for performing a programmed work It is then a matter of engineering to make function to subordinate to will The motor s source of current must therefore in some way receive impulses from the neuromuscular system

The questions we have asked ourselves have been

1 Do myopotentials exist in an amputated arm some time after the amputation has been performed and are these suitable as impulses for the servo-hand?
2 Can a motor be constructed that is sufficiently small and light to be inserted in a hand prosthesis and still be effective enough to perform useful work?

The problems outlined above have been studied in several research centres and hand prostheses have been constructed which have functioned during laboratory tests

In our efforts to develop practically useful prostheses we have drawn up the following ideals

1 The myopotentials should be derived so that a permanent and steady arrangement results which does not harm the patient
2 The servo-hand should be so constructed that its functional scope

This investigation has been supported by a grant from the Swedish Medical Research Council

can be simply adapted to cover a sufficiently wide register of movements and power output
3 The impulses should preferably not be initiated only by the will but also be regulated or in some way quantitized in order to make a wider functional scope possible The amputated person should be able both physiologically and psychologically to adapt himself to the system

When controlling a prosthesis it is important that the control signals are natural for the individual in question One type of such natural signals can be taken from the mechanical activity of another muscle which is intact or from the muscle stump of an amputated extremity via transducers The fact that there is a proportion between the mechanical activity of the muscle and its action potentials is a prerequisite for the use of action potentials when controlling a prosthesis This had also been taken advantage of as may be seen from works by *Battey Nightingale & Whillis* 1955 *Kobrinsky et al*, 1960 and *Horn*, 1963

Muscle action potentials derived from the muscle of an extremity show considerable variations with regard to the amplitudes even though *conditions have been constant These variations are so great that they* might possibly render it difficult to use myopotentials in controlling a prosthesis We have therefore wanted to investigate whether filtration of the myosignals could reduce this difficulty Furthermore we have wanted to get an idea as to the psycho physiological possibilities of test persons to use their myopotentials quickly and correctly in a test programme *Finally* we have converted our experience into a servo prosthesis the actuator system of which shows force velocity relations comparable to those that are to be found in a striated muscle

## *RESULTS*

### 1 *Frequently amplitude Relation in Muscle Action Potentials*

When skin electrodes are used it is possible to derive muscle action potentials within the frequency range 25 Hertz to 1 000 Hertz and to obtain amplitudes from some microvolts to millivolts The frequency range of the potentials varies in different muscle groups Figure 1 shows the course of the frequency amplitude in myopotentials derived from M biceps brachii There is maximum activity in the range about

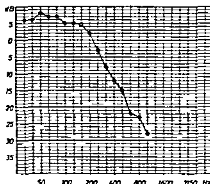



*Fig 1*

Frequency amplitude responses obtained with a number of ⅓-octave filters Abscissa frequency in Hertz ordinate relative output amplitude in dB

50 Hertz At higher pass band frequencies there is a strong reduction of the amplitude

In a previous work (*Kaiser & Petersen* 1963) an analytic method to obtain simplified data with regard to the frequency profiles of the myopotentials has been described On the basis of the results of this work an automatic broad band frequency analyser for EMG was constructed This analyser (to be published *Kaiser & Petersen* 1964) has been used in the present work utilizing primarily three one-octave filters

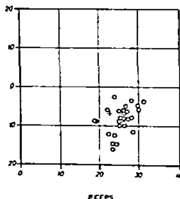



*Fig 2*

Shape of frequency profile obtained via three broad band filters (one octave) M biceps brachii Skin electrodes Abscissa Ratio between filter output 200 Hertz and filter output 800 Hertz expressed in dB Ordinate Ratio between filter output 200 Hertz and filter output 50 Hertz expressed in dB

Fig. 2 shows a number of loci which indicate the form of some frequency profiles of the same type as in Fig. 1. As a reference amplitude the area about 200 Hertz has been used. The abscissa shows the ratio between amplitudes in the 200 Hertz range and the 800 Hertz range expressed in dB. The point marked + corresponds to the curve in Fig. 1. It can be observed that the activity at 800 Hertz lies 22 dB lower than the activity at 200 Hertz (the abscissa) and that the 200 Hertz activity lies 7 dB lower than the 50 Hertz activity (the ordinate). The circles in Fig. 2 show the frequency profiles in 27 derivations with skin electrodes from biceps muscles. It can be observed that the greatest amplitude reductions below 200 Hertz amount to approximately 30 dB, *i.e.* to about 3 per cent of the 200 Hertz activity. The greatest difference between the 50 Hertz and the 200 Hertz areas amounts to about 16 dB, *i.e.* the 50 Hertz activity can be up to six times greater than the 200 Hertz activity. The greatest difference between the 50 Hertz activity and the 800 Hertz activity is 40 dB, *i.e.* the 50 Hertz activity is about 100 times greater than the 800 Hertz activity.

## 2. *Choice of Proper Filter Range*

The great amplitude reduction at high frequencies referred to above might indicate that the range about 50 Hertz would be the one most suitable for the purpose. There are two factors, however, which must be recognized at this point: *a*, the myopotential fluctuations of an erratic nature mentioned in the introduction and *b*, outside interference such as alternating current interference (power line noise) of 50 Hertz and their harmonics. Both of the difficulties mentioned under *a* and *b* may be overcome by choosing a proper filter range.

Fig. 3 shows, in a logarithmic scale, the output voltages from four different filters which each have a band width of one octave. These voltages have been obtained logarithmically direct from the analyser. The uppermost curve shows the activity at 50 Hertz, curve no. 2 at 200 Hertz. Curve nos. 3 and 4 which partly coincide show the activity at 400 resepectively 800 Hertz. The fact that these two lines partly coincide does not mean that the two voltage levels are alike. Actually the 800 Hertz level lies 11 dB lower than the 400 Hertz level. The test person has tried to keep the muscle contraction at a constant level during the course of ten seconds. The distance between the horizontal lines corresponds to a change of the potential level of about 40 per cent. The peak to peak deviations in the 50 Hertz filter correspond to

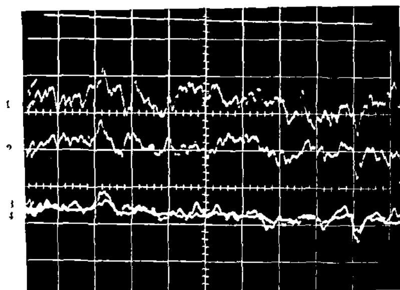



*Fig 3*

Logarithmic output voltages from four filtres band with one octave Logarithmic scale *Above* filter output for 50 Hertz centre frequency *Middle* filter output for 200 Hertz centre frequency *Below* two partly coinciding curves filter output for 400 respectively 800 Hertz centre frequency Abscissa the distance between vertical lines = 1 sec Ordinate the distance between horizontal lines = 4 dB

a ±20 per cent voltage change at 200 Hertz ±12 per cent at 400 Hertz ±7 per cent and at 800 Hertz ±4 per cent This shows that filters with passband which cover 300–1 000 Hertz can reduce the tendency towards interference in a very efficient manner because the interference reduces more than the potential level itself when the frequency increases As a result of this the difficulty due to myopotential fluctuations have been reduced to a tolerable level The improvement is probably due to the fact that the filters with higher passband frequencies give single potentials with shorter duration than the filters with low frequency which reduces the chances of interference

*b* A C interferences too are controlled by choosing filters with pass band The cut off frequency 300 Hertz protects against 50 Hertz A C interferences and against up to the 5th harmonic

### 3 *Myoelectrical Level Changes in a Test Programme*

The following tests were made in twelve normal test persons for the purpose of determining the possibilities of a normal arm muscle to

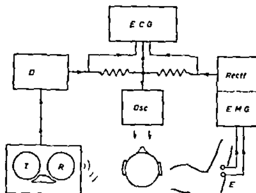



*Fig. 4*

Schematic presentation of the test set up for programmed muscle activity under bioelectrical control. E = skin electrodes. EMG = EMG apparatus. Rectf. = rectifier for output potentials. OSC = cathode ray oscillograph in bridge coupling. ECG = ECG apparatus. Discr. = frequency discriminator. T.R. = tape recorder.

give myopotentials quickly and accurately in accordance with a predetermined programme. The investigation which is illustrated in Fig. 4 was carried out in the following manner. Skin electrodes E were attached to the forearm of the test person and were connected to a Disa EMG apparatus with a rectifier unit which produced a D.C. voltage proportional to the muscle action potentials (not filtered). At the same time a simple melody (Brother Jacob) was played on a tape recorder (T.R.) which was connected to a frequency discriminator, *i.e.* an electronic circuit which produced voltages that were proportional to the pitch of the tone played. These output voltages and the voltages of the myograph could compensate one another via a bridge circuit connected to a cathode ray oscillograph. The test person could both hear the melody and simultaneously follow visually on the screen of the cathode ray oscillograph how he compensated with his muscle activity the potentials reproduced in conjunction with the melody. All potentials were registered on an ECG apparatus. The results of such an investigation may be seen in Fig. 5. Curve A shows the time lapse of the output voltages of the discriminator which reflect a part of the melody. Curve B 1 shows *the rectified and somewhat smoother myopotentials* which are received from the test person when by visual control he tries to compensate the voltage niveau programme produced with the melody. Curve B 2 shows how the test person succeeds in trying to compensate. As may be seen, the deviations from the ideal result (a stright line) amount to 20 microvolts at a mean level of 50 microvolts. The deviation

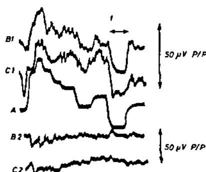



Fig 5

Time lapses of integrated potentials in a test programme A = test programme B 1 = course of the potential under visual control B 2 = result of the compensation C 1 = course of the potential without visual contdol C 2 = result of the compensation Abscissa time Ordinate amplitude

at lower levels (down towards 10 microvolts) was procentually just as great and had a reasonable proportion to those determinations which have been mentioned above (±20 per cent) Curve C 2 shows the person s ability to reproduce his contraction programme when he hears the melody but has no access to visual control The nature of the compensation is here of another type In the successful tests it can be seen (C 1) that the level changes without visual control are developed quicker but with less precision than with visual control The result of the compensation may be seen by C 2 which shows less quick deviations but greater level changes than in B 2

When no visual control is used an overshooting occurs in the compensating activity at the onset of pitch changes This activity pattern with its tendency to overshooting is actually advantageous for the utilization of a motor operated prosthesis as the initiated force should be greater than the stationary Muscle potentials and possibly peripheral nerve action potentials have dynamic advantages in a prosthesis servo system because they are in themselves intended for servo systems and are therefore to be preferred to signals generated more central in the nervous system

4 *Servo prosthesis*

The principle for the servo system that we have arrived at is shown in Fig 6 The myopotentials are derived by means of bi polar skin electrodes The registered potentials are amplified by means of a difference

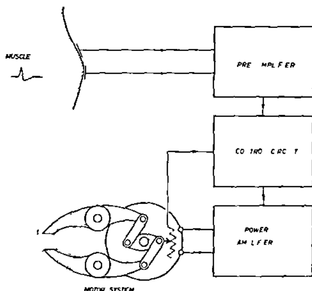



*Fig 6*
Schematic presentation of a bioelectric controlled servoprosthesis

pre amplifier with a range of 300–1 000 Hertz. Input impedance is *300 000 Ohm. The voltage gain is adjustable up to a maximum of 100* dB. The output impedance is 1 000 Ohm. The outgoing voltages are transferred to a servo system, the control circuit of which contains a rectifier for the myosignals. The analog direct current component produced in this manner is led to a bridge circuit which compares the myosignals to a change of resistance created by the position of the prosthesis. If there is a discrepancy between the myosignals and the corresponding equilibrium position in the prosthesis, the bridge connection will produce d.c. potentials. These potentials are amplified in the power amplifier and are transferred to the servo motor. This gives an automatic adjustment of the prosthesis in relation to the controlling signals. By means of the servo loop, the working range of the prosthesis may be adjusted according to need.

The static force of a grasp obtained through the current is within certain limits proportional to the difference between the actual position of the prosthesis and the position which the prosthesis would assume at the same activation but without outer load. The servo amplifier produces voltages of up to ±2.5 volts d.c. The current goes up to 600 milliampere. The maximum output effect is obtained at control voltages which exceed 1.5 volts d.c.

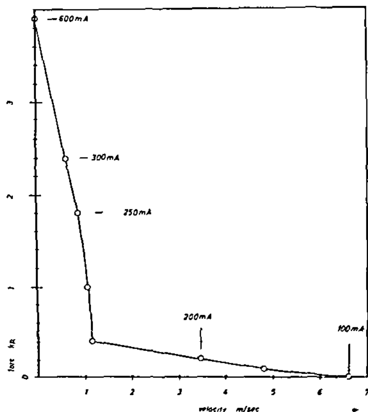



*Fig 7*

Force velocity at maximum activation of the prosthesis motor system. Abscissa velocity in cm/sec. Ordinate force in kp.

## a *The Motor System*

An ideal force-velocity relation would be obtained by using a so-called series motor of principally the same type as the one used for starting an automobile motor. Such a motor however is rather uneconomic in a miniature design. It is necessary to use motors with permanent magnets in order to obtain a reasonable electro-mechanical efficiency. The use of motors with permanent magnets means that the velocity force relation will be less suitable for these purposes. In order to counteract this difficulty we have used an automatic coupling to combine two miniature motors in such a manner that there is a suitable distribution of work between the two motors. Motor no. 1 produces the quick movements with relatively little force. Motor no. 2 additionally

produces a relatively great force in combination with slow movements During purely static conditions (i e when the prosthesis is fixed in a grip around an object) motor no 2 need not be activated as motor no 1 keeps the prosthesis locked with a minimum of current A real relaxation is not possible until there is a change of the current direction in the motor system By using this arrangement there is an optimal electro mechanical function both during dynamic and static conditions Furthermore a force velocity relation similar to that of a striated muscle is obtaineed Fig 7 shows the current which is necessary to give maximum force at different speeds expressed in cm/sec At the present transmission ratio the maximum force during purely static conditions is 3 9 kp and that it is obtained at a current of 600 milliampere In addition Fig 7 shows that a maximum velocity of 6 6 cm/sec without load is obtained at 100 milliampere From the maximum velocity down *to 1 cm/sec a force which increases with reduced velocity up to about* 0 4 kp (400 gm ) is obtained This part of the diagram corresponds to the effect of motor no 1 The next part of the diagram for velocities below 1 cm/sec (after the knee of the diagram) shows the effect of motor no 1 + motor no 2 Here one can see a smooth relation with additionally increasing force as the velocity decreases The current at the point where motor no 2 is just starts its contribution is about 200 milliampere At lower activation levels one obtains curves which are parallel to the one shown and which lie between the one shown and the two coordinate axes

## DISCUSSION

### *Regarding the Suitability of Electrical Signals in Servo System*

The choice of signalling muscle activity via the action potentials or via the mechanical activity produced is dependent on several factors for instance *a* the availability of the signals *b* its usefulness seen from the point of view of graduation and speed

*a* Regarding the availability of the signal the prerequisites probably are the same whether one uses action potentials or the mechanical activity Both skin electrodes as receivers of electrical activity as well as an external transducer for mechanical signals require a mechanical contact with the extremity The possibility of outside interferences of a mechanical nature is probably greater when the mechanical transducer *is used as electrical interferences only can come into question when* the electrical signals are to be received Such interferences however can easily be avoided by means of a suitable filtration technique

When implanted units are used for receiving mechanical or electrical activity the mechanical problems of the transmission are reduced and in both cases there is a possibility of obtaining a more undisturbed electrical transmission of both the mechanical and the purely electrical signals In this case there will be interferences only if the electro mechanical transducer is subjected to an unintentional external pres sure the purely electrical system however is insusceptible in this respect

*b* The usefulness of mechanical and electrical signals from the point of view of graduation is expected to be somewhat better than is the case with the mechanical signals On the other hand the myosignals are quicker than the mechanical ones In cases of level changes a quickness via the myopotentials is therefore obtained which is reduced only by the dynamic characteristics of the servo system

*Regarding Electrodes*

In electromyography needle electrodes usually are used Owing to the risk of pain and infection this type of electrodes of course is im possible to use in controlling a prosthesis

Another possibility is skin electrodes These too would involve con siderable inconvenience when used for a prolonged period of time

Another possibility which may be realized thanks to modern micro electronics is to create a small electronic circuit for implantation under the skin so as to obtain a closer contact with the muscle Such a circuit may be energized from the outside and can transmit electro magnetic signals of high frequency through the skin We are in the process of working on such a circuit

*Regarding Choice of Filter*

The potentials which can be registered by skin electrodes represent statistically a small part of the total activity in the different motor units of the muscle It is therefore clear that among the few registered potentials individual potentials will play a greater role in relation to the registered muscle activity This is one of the reasons for the erratic nature of myopotentials derived from a small area Another reason is the severe interference between the components with low frequencies The chance of interference between potentials in different motor units grows with the quotient of the duration of the single potentials and the time interval between action potentials One would expect that an in

crease in the contraction force would give a relatively smaller erratic activity owing to the greater number of potentials per time unit but unfortunately this is compensated by the interference mentioned previously Therefore we chose to investigate whether the interference phenomenon could be reduced by a suitable choice of filter

We found that filters with passbands 300–1 000 Hertz were especially suitable for solving certain problems *viz* both the power line noise amounting to 50 Hertz and the unsuitability of the unfiltered muscle action potentials (owing to their erratic nature) This is especially interesting considering some of the statements made in literature on the subject *Battey et al* (1955) state that the most favourable range is 100 to 1 000 c/s but do not justify their statement *Horn* (1963) also uses the range 100 c/s to 1 000 c/s This author considers it justified to neglect the information from the range below 100 Hertz owing to power *line noise As may be seen from the above we have, however shown* that contrary to this it is rewarding to neglect information all the way up to 300 Hertz as the information in the range below 300 Hertz contains *erratic components which are too great*

*Regarding the Transmission System*

The fact that our transmission system holds the prosthesis locked in a grasp until there is a change of the current direction in the motor system is a pre requisite for good Watt economy in the servo system during static conditions as a result the advantage of saving energy that is to be found in pneumatic systems during static conditions has been matched

Figs 8 and 9 show the artificial hand with its electromechanical system

Our solution with miniature motors placed in the artificial hand involves rather great mechanical demands of a qualitative nature The possibility of placing electrical motors of larger size outside the hand but with a purely mechanical or hydraulic transmission should not be overlooked On the whole it is our opinion that with respect to different types of prosthesis systems one should not commit oneself to one type or another without gaining experience based on research or practice which will indicate the most suitable system for the work to be done at home at work or during spare time occupation It may also be necessary to try a combination of several systems

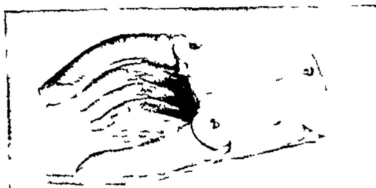


*Fig 8*
The exterior of an artifical hand containing a servomotor system

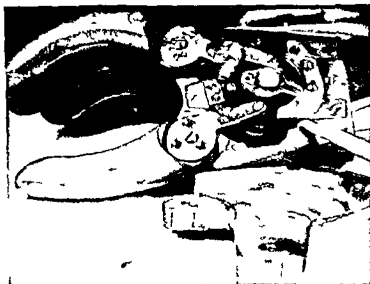


*Fig 9*
The electromechanical feedback system in the hand

SUMMARY

1 Muscle action potentials from M biceps brachii were derived with skin electrodes They were analysed with octave band filters in order to determine the informational value in the different frequency ranges between 30 and 1 000 Hertz Although the greatest activity is to be found

at frequencies of 200 Hertz and below we could show that the informational value of muscle action potentials in the range 300–1 000 Hertz is considerably greater because the interference disturbance between different motor units decreases more when the frequency is increasing than the signal level itself

2 A number of test persons were investigated with respect to their ability to follow a test programme by means of muscle contraction

3 A transmission system with two miniature motors is presented The advantages with regard to work distribution between the two motors (force velocity relation) are discussed

4 A proposed servo system is presented and discussed


## RESUME

1 Des potentiels d action musculaire a partir des M Biceps Brachii furent derives avec des electrodes en peau Ils furent analyses avec des filtres ayant une largeur de bande d une octave afin de déterminer la valeur d information dans les differentes gammes de frequence entre 30 et 100 Hz Bien que la plus grande activite se retrouve a des frequences de 200 Hz et moins nous avons pu montrer que la valeur d information des potentiels d action musculaire dans la gamme de 300–1000 Hz est sensiblement plus grande en raison du fait que la perturbation d interference entre differentes unites motrices diminue beaucoup plus quand la frequence croit que le niveau meme des signaux

2 Un certain nombre de personnes furent testees pour deceler leur aptitude a suivre un programme de test au moyen de la contraction musculaire

3 Un systeme de transmission a deux moteurs miniatures fut presente Les avantages quant a la distribution du travail entre deux moteurs (rapport puissance/velocite) sont discutes

4 Un servo systeme propose est presente et discute



## ZUSAMMENFASSUNG

1 Muskelaktionspotentiale vom Musculus biceps brachii wurden mit Hautelektroden abgeleitet Sie wurden mit Oktavbandfiltern zur Erforschung des Informationswerts in den verschiedenen Frequenzbereichen zwischen 30 und 1000 Hz analysiert Obwohl die grosste Aktivität bei Frequenzen um 200 Hz und niedriger liegt konnte nachgewiesen werden dass der Informationswert der Muskelaktionspoten

triale im Bereich 300–1000 Hz erheblich grösser ist weil Interferenz störungen zwischen verschiedenen Motoreneinheiten bei steigender Frequenz stärker abnehmen als das eigentliche Signalniveau

2 Eine Anzahl von Versuchspersonen wurde im Hinblick auf ihre Fähigkeit untersucht einem Testprogramm durch Muskelkontraktionen zu folgen

3 Ein Impulsübertragungs und Kraftüberführungssystem mit zwei Motoren wurde beschrieben und die Vorteile bei Berücksichtigung der Arbeitsverteilung zwischen den beiden Motoren wurden diskutiert

4 Eine Lösung zum Servosystem wurde vorgeschlagen und diskutiert

## REFERENCES

*Battye C K Nightingale A & Whillis J* The use of myo electric currents in the operation of prostheses J Bone Jt Surg 37 506–510 1955

*Horn G W* Electromyographic signal produced by muscle movement controls grasp of prosthetic fingers Electronics October 11 Vol 36 35–36 1963

*Kaiser E & Petersen I* Frequency Analysis of muscle action potentials during tetanic contraction Electromyography 3 5–17 1963

*Kaiser E & Petersen I* To be published

*Kobrinsky A F Bolkovin S V Voskabrinikova L M Ioffe D M Polyan E P Slavitskii Y A L Sysin A Yu & Jacobson A S* Problems of automatic control Proc Automatic Control Conference Moscow p 1119 Butterworth Pub., London

Acta orthop Scandinav XXXI 16-20 1964

From the Department of Surgery II Sahlgrenska Sjukhuset
University of Gothenburg Sweden (Head Professor Ragnar Romanus M D )

# REFRACTURE OF THE SHAFT OF THE FEMUR

By

HANS DENCKER

Refracture is a complication of fracture of the femoral shaft relatively seldom mentioned in the literature For instance in the major series published by *Bohler* (1951), *Street* (1951) and *Key & Lottes* (1951) no such complication was noted On the other hand *Stuck & Crebe* (1948) recorded refracture or secondary fracture in 21 of 124 and *Hartmann & Brav* (1954) in 12 of 135 cases

During recent years several authors have reported bone absorption and refracture so called encircling fracture after fixation with encircling wire or bands (*Olsson* 1949, *Arnesen* 1951 *Storen* 1958)

The cause of bone absorption around encircling wires has not been established with certainty It would appear to result from movements of the fracture ends (*Arnesen Storen*) Other factors which may be of importance are the character of the fixation material corrosion and infection *Olsson* s report of 44 different fractures treated with encircling wire described bone resorption around the wire in 9 cases and spontaneous fracture in 3 *Arnesen* s investigation of 43 different fractures treated with encircling wire absorption around the wire occurred in 2 cases 1 of which was accompanied by spontaneous fracture

## MATERIAL

The investigated series of femoral shaft fractures altogether 1 003 was collected from practically all Swedish hospitals during the three years between 1952 and 1954 The material comprises fractures mainly situated in the middle three fifths of the femur of patients 17 years old or more where there was no probability of tumour involvement Fracture healing can be evaluated in 837 of the 1 003 fractures

A new break at or close to the old fracture which was regarded as healed is here termed refracture

There was no significant difference in the incidence of refracture between different methods of treatment of either closed or open fractures (Tables 1 and 2)

TABLE 1

*Closed Fractures Frequency of Refracture*

| Method of treatment | Total fractures | Refractures | |
|---|---|---|---|
| | | No | |
| Closed methods | | | |
| Traction | 196 | 2 | 1 |
| Others | 6 | – | – |
| Open methods | | | |
| Intramedullary nailing | 364 | 8 | 2 |
| Encircling wire | 83 | 3 | 4 |
| Plate and screws | 43 | – | – |
| Others | 45 | 2 | 4 |
| Transfixation | 4 | 1 | (25) |
| Total | 741 | 16 | 2 |

TABLE 2

*Open Fractures Frequency of Refracture*

| Method of treatment | Total fractures | Refractures No |
|---|---|---|
| Closed methods | | |
| Traction | 32 | 3 |
| Other | 1 | – |
| Open methods | | |
| Intramedullary nailing | 40 | – |
| Encircling wire | 4 | – |
| Plate and screws | 7 | – |
| Others | 9 | 1 |
| Transfixation | 3 | – |
| Total | 96 | 4 |

In 17 of 20 cases refracture occurred in connexion with a new accident In 3 there was no trauma Eight patients sustained refracture within four months 9 between four and twelve months and 3 more than twelve months after the original fracture had united

The extent of bone absorption—as observed on the roentgeno...

and therefore representing minimum values—amounted to between 1 mm and 3 mm in 17 and between 4 mm and 6 mm in 3 of 87 fractures treated with encircling wire Two cases in which refracture resulted from bone absorption around the wire are here reported briefly

No 865 Male 46 years fell on March 29 1954 and sustained an oblique fracture midway along the left femoral shaft Traction was applied through the distal part of the femur Operation on April 1 Fixation with 2 encircling wires + plaster immobilization The fracture was united 7 months after the operation There was at that time bone absorption of 1 to 2 mm at both wires These were not extracted On October 4 1955 about 18 months after the accident the patient experienced pain in the left thigh not connected with any trauma Roentgen examination revealed an oblique fracture at the same site as the original one The refracture started at the level of the proximal wire There was about 3 mm bone absorption at both wires Operation on October 12 Extraction of encircling wires + intramedullary nailing + grafting with bone chips from the iliac crest The postoperative period was uneventful The fracture was healed 6 months after the nailing operation

No 2308 Male 21 years fell off a fence on August 25 1952 and sustained a long oblique fracture in the lower third of the left femoral shaft Traction was applied through the tibial tuberosity Operation on September 10 Fixation with 2 encircling wires + plaster immobilization Roentgen examination on December 6 1952 showed the fracture to be united There was at that time bone absorption measuring around 2 mm at both wires These were not extracted On March 29 1953 sudden pain developed in the left thigh without any preceding trauma Roentgen examination revealed refracture at the level of the proximal wire There was about 2 mm of bone absorption at each wire The refracture was at first treated with traction followed by plaster immobilization No extraction of the wires The fracture was healed after 5 months At this time there was about 1 mm of bone absorption at the distal wire No further roentgen examinations were made

## DISCUSSION

Refracture supervened in 20 cases of 837 evenly distributed among the different methods of treatment In most instances it was connected with a new trauma If these patients had exerted more caution during the year following the fracture the second break might have been avoided Almost invariably the refracture occurred within this period

Most authors recommend that encircling wires should be extracted as soon as healing permits (*Olsson* among others) In both encircling fractures there was between 1 mm and 2 mm of bone absorption at the wires 3½ and 11 months respectively before the date of the new break Had the fixation material been extracted at that time refracture might possibly have been prevented since it was in neither instance preceded by any trauma

SUMMARY

Refracture occurred in 2 per cent of the femoral shaft fractures which were treated at Swedish hospitals during the three year period 1952 to 1954 The complication was of roughly equal incidence in the different treatment groups Two of the 87 fractures treated with encircling wire were accompanied by encircling fracture

RÉSUMÉ

Examen de nouvelles fractures qui se sont produites dans 2 pour cent des cas de fracture du corps du fémur traités dans les hôpitaux suédois pendant la période de trois ans 1952 à 1954 La complication présentait dans l ensemble la même incidence dans les différents groupes de traitements Deux des 87 fractures traitées par encerclage présentaient une fracture d encerclage

ZUSAMMENFASSUNG

Refraktur trat in 2 Prozent der Femurschaftbrüche auf die an schwedischen Krankenhäusern während der Dreijahrsperiode 1952 bis 1954 behandelt wurden Die Komplikation ereignete sich ungefähr mit glei cher Häufigkeit in den verschiedenen Behandlungsgruppen Zwei der 87 Brüche, die mit Drahtumschlingung behandelt wurden waren von einem kreisförmigen Bruch begleitet

REFERENCES

*Arnesen A J A* Encircling suture (cerclage) in oblique fractures Acta chir Scandinav *10* 267 1951/1952

*Böhler J* Results in medullary nailing of ninety five fresh fractures of the femur J Bone Jt Surg *33-A* 670 1951

*Dencker H W* Fractures of the shaft of the femur A clinical study based on 1 003 fractures treated in Swedish hospitals during the three year period 1952 to 1954 Orstadius boktryckeriaktiebolag Göteborg 1963

*Hartmann F R & Brav F A* The problem of refracture in fractures of the femoral shaft J Bone Jt Surg *36-A* 1071 1954

*Key J A & Lottes J O* Medullary fixation of the femur Complications and errors in technique Am Acad Orthopaedi Surgeons *Instructional Course Lectures* *8* 27 1951

*Olsson O* Some cases of necrosis of the bone by encircling suture (cerclage) in oblique fractures Acta chir Scandinav *99* 85 1949/1950

*Street D M* One hundred fractures of the femur treated by means of the diamond shaped medullary nail J Bone Jt Surg *33-A* 659 1951

*Stuck W G & Grebe A A* Complications of treatment of fractures of the shaft of the femur Sth Surg *14* 735 1948

*Storen H* Two cases of encircling fractures Acta orthop Scandinav *28* 147 1958/1959

5)

Acta orthop. Scandinav. XXXV, 21–38, 1964

From the Clinic for Orthopaedics and Traumatology, University of Helsinki (Chief: Prof. K. E. Kallio) and from the Department of Forensic Medicine, University of Helsinki (Chief: Prof. U. Uotila)

# THE REPAIR OF EXPERIMENTAL FRACTURES DURING LONG-TERM ANTICOAGULANT TREATMENT

*An Experimental Study on Rats*

*By*

P. ROKKANEN and P. SLÄTIS

Little has been written concerning the effect exerted by anticoagulant treatment on the healing of fractures. *Stinchfield, Sankaran & Samilson* published in 1955 their observations on the effect of heparin and dicumarol as regards the healing of spongy bone transplants. In their experiment the consolidation of an autologous spongy bone transplant on the crest of the ilium was studied in rabbits and dogs. Both heparin and dicumarol caused delayed formation of new bone with marked appearance of fibrous tissue. The delaying effect of anticoagulant treatment on the formation of callus was most clearly observable in the animals to whom both heparin and dicumarol were administered immediately after the operation. Later *Minola, Nasta & Granato* (1958) found in their work concerning experimental radius fracture in rabbits that heparin and dicumarol produced a persistent fracture haematoma and a more marked and prolonged cartilaginous stage in the fracture repair. On the other hand *Aulisa* (1960) in his studies of experimental tibial fracture in guinea pigs could not demonstrate any distinct differences between heparin treated animals and controls.

Since the observations made by *Stinchfield et al.* may possess practical significance, attention has been paid in our Clinic to the potential effect of anticoagulant treatment on fracture repair. In addition to a clinical study (*Solonen* 1963), the present experimental study is intended to serve the purpose of clarifying the effect of long-term anti-

---

This work has been aided by an institutional grant from the Sigrid Juselius Foundation, Helsinki, to the Department of Forensic Medicine, University of Helsinki.

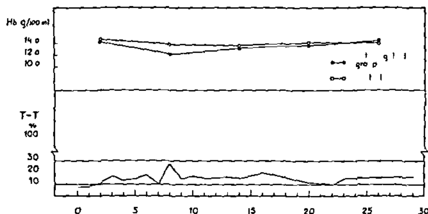



*Fig 1*

Haemoglobin values and prothrombin variations by Owren s TT method in the test groups at different times after commencement of the anticoagulant treatment

coagulant treatment on the healing of experimental diaphyseal fractures

## MATERIAL AND METHODS

In the experiments 70 white female rats of 5–6 months age and weighing between 138 and 180 g were expended The right tibia was fractured by hand in ether narcosis and no subsequent fixation was applied (cf *Koskinen* 1959) Long term anticoagulant treatment was given to 45 animals the fracture being produced in 30 of them after commencement of this treatment while in the case of the other 15 animals the anticoagulant treatment was started on the third day after the fracture 25 animals constituted a control group The animals were sacrificed and the fracture areas examined at intervals of six days the oldest animals being sacrificed 30 days after the operation

As *anticoagulant agent* the preparation Sintrom ® (Geigy) of dicumarol type was used The effect of the anticoagulant treatment was checked by *Owren* s (1959) TT method which was found in preliminary tests to be applicable to rats Initially the TT variations were checked daily until a stable therapeutic level of 10 15 per cent had been reached The haemoglobin values were checked at varying times after commencement of the anticoagulant treatment No significant differences in respect of haemoglobin values could be established in comparison with the control group (Fig 1)

After each animal had been sacrificed *roentgenologic examination* of the fracture was carried out and a print was made of the roentgenograph at 5 × magnification For accurate determination of the callus size the contour of the callus as seen in the print was traced by pencil and the area of the resulting figure was determined with the planimeter For *histologic examination* the specimen consisting of the fractured area was fixed in neutral formalin and decalcified by the EDTA method Cuts made in the sagittal plane were stained by the haematoxylin Weigert van Gieson or the eosin haematoxylin method The histo hemical meth d employe l in this work was

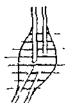


*Fig. 9.*
Illustrating the procedure in the line sampling analysis of the callus components. The occurrence of the different tissue components was recorded along transects drawn at right angles to the proximal bone fragment at intervals of one diameter of the microscope's field of vision. Depending on the size of the callus, the number of transects varied between 4 and 10.

*Steedman's* (1950) alcian blue staining in *Lison's* (1954) modification. The methyl metacrylate specimens which had been subjected to autoradiographic and microradiographic examination were ground down to 25–40 μ thickness and they, too, were stained with alcian blue upon removal of the metacrylate. The *line sampling method* devised by *Lotila* (1940) and by *Lotila & Kannas* (1952) is a histo-quantitative method previously employed by *Koskinen* (1959) in determination of the callus components. This method enables, with the aid of a microprojector, the different tissue components in the histological specimen under investigation to be quantitatively differentiated. The procedure employed in this investigation is illustrated by Fig. 9. On a number of transects drawn across each cut and spaced at distances equal to the diameter of the microscope's field of vision, the linear contribution of each of the following types of tissue components was recorded: new bone, cartilage in the process of becoming bone, hyaline cartilage, fibrous tissue and bone cavities. The total transect length found for each component was then expressed in per cent of the sum of the transect lengths. A check of the method made by repeating the procedure a few times with one and the same specimen but with the lattice formed by the transects displaced by various fractional parts of the transect spacing produced results on the strength of which the percentages found by one single determination as described can be considered reproducible within 3–5 per cent units.

*Autoradiographic examination* was undertaken in the case of 22 animals. They were given radioactive phosphorus $P^{32}$ in the form of phosphate at a dosage of 1 microcurie per gram of body weight by intraperitoneal injection 4 hours prior to sacrificing. Specimens of the fracture area embedded in methyl metacrylate were ground down to about 80 μ and autoradiographs were made on Kodak Fast Autoradiographic Stripping Plates AR 10 with Kodak D 19b developer and 6 weeks exposure.

*Microradiographic examination* was performed on the same specimens as had been subjected to autoradiography. A Philips X-ray Apparatus type 11 04 and Kodak Spectroscopic Plates 649 GH were used in this study.

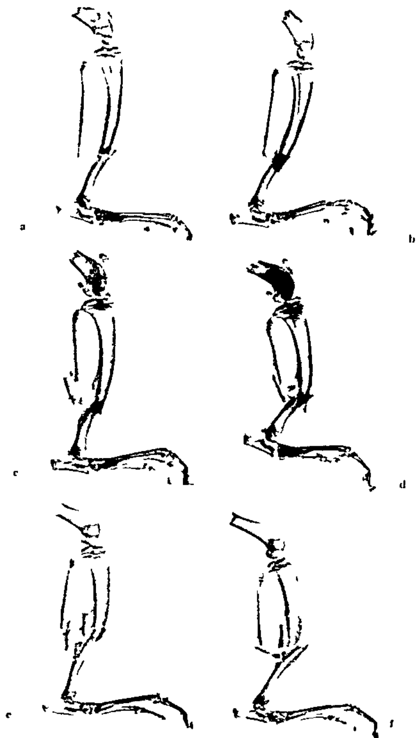



*Fig. 3*

## RESULTS

During the tests two animals in the anticoagulant treatment groups were lost owing to haemorrhage —In the test groups as well as in the control group the fractured extremity was as a rule sufficiently stable after 18 days to bear weight normally In the anticoagulant treatment groups a larger size of the callus by palpation was found as compared to the control group although no distinct difference could be manually observed in the solidity of the fractured bone Two instances of pseud arthrosis were noted in the control group but none in the anticoagulant treatment group

### *Roentgenologic Changes*

12 days after the fracture it was already observable in the roentgeno graphs that the callus area was clearly larger in extent in the anti coagulant treatment group than in the control group The differences became even more marked in the further course of the tests (Fig 3)

The fractures were similar in the different animals In the subjects of the anticoagulant treatment groups a sizeable callus of loose structure was seen There were occasional radiolucent spots and even changes resembling cysts (Fig 4)

Measurements of the longitudinal extension of the callus by the roent genographs revealed that this dimension was greater in the anticoagu lant treatment group by 9 per cent on the anterior and by 29 per cent on the posterior side than in the controls The differences between the groups as regards callus size are readily evident in the graphs showing the callus areas found by planimetration (Fig 5)

In the test group consisting of animals whose fracture had been produced during anticoagulant treatment the measured callus was nearly twice as large as in the control series In addition the animals in whose case the anticoagulant treatment had not been commenced until three days after the fracture showed a clearly observable devia tion from the control series in this respect

---

*Fig 3*

Roentgenographs of the fractured tibia of animals 12 18 and 24 days after the fracture revealing a greater amount of callus in the animals under anticoagulant treatment (a c e) than in the controls (b d f)



*Fig 4*
Cyst like radiolucent spots in the callus of an animal subjected to anticoagulant treatment Roentgenograph taken 30 days after the fracture

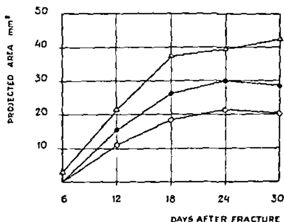



*Fig 5*
Area of the callus hadow in the roentgenographs determined by planimetry
△——△ Anticoagulant treatment in progress when the fracture was induced
●——● Anticoagulant treatment commenced on the third day after the fracture
○——○ Controls

*Histologic Changes*

In the subsequent histological description the normal repair process of the bone encountered in the control group are presented while with regard to the anticoagulant treatment groups only circumstances indicating deviation from this normal behaviour are brought to the fore

In the control series the ends of the fragments were surrounded after 6 days by a haematoma which was in its turn encircled by fibrous tissue The osteogenic layer of the periosteum was thick and proliferative close to the point where it was detached from the bone surface In this collar of the periosteum new bone was already seen in scanty amount at this stage Adjacent to it some hyaline cartilage was seen and more peripherally fibrous tissue In the ends of the fragments some bone cavities were anuclear and the bone itself displayed poorer stainability In the animals under anticoagulant treatment the formation of new bone in the collar started as in the controls but the associated hyaline cartilage was more abundant

After 12 days signs of haematoma were still visible between the fragments in the control series Formation of new bone was in progress closer to the centre and the hyaline cartilage was scanty The connective tissue zone observable on the margin of the callus was wide and the periosteum was thicker than before In the anticoagulant treatment groups ossification took place in the same area as in the controls The callus was considerably richer in hyaline cartilage and larger on the whole The fragments were mutually connected in some places by a cartilaginous bridge in addition to the fibrous zone It could also be seen that detachment of the periosteum had occurred over a wider area than in the controls

After 18 days the callus in the controls was seen to be composed of new bone and fibrous tissue Hyaline cartilage occurred but little The callus was scanty in quantity and the process of ossification was moving into the area between the fragments In one of the cuts bony consolidation was seen between the fragments In the anticoagulant treatment groups the callus was still greater and more hyaline cartilage dominated Ossification of the callus was in progress from both fragments outwards though on the other hand independent centres of ossification could be observed on the marginal areas of the sizeable callus (Fig 6)

After 24–30 days still a scanty and mainly fibrous callus was encountered in the control series The hyaline cartilage was exceedingly scanty The fractures showed bony consolidation except for two cases in which the fragments were joined merely by a fibrous callus At the



*Fig 6*

Histological micrograph of a specimen taken 18 days after the fracture of an animal whose fracture had been induced during anticoagulant treatment
Abundant cartilaginous tissue is seen in the large sized callus — Alcian blue stain magnification 50 ×

ends of the fragments anuclear areas of large extent were encountered but new bone occurred in close association with this necrotic area In the anticoagulant treatment groups even now hyaline cartilage could be seen in greater abundance than in the controls The process of new bone formation had moved into the space between the fragments and in some cuts bony consolidation could be seen to have occurred in the marginal parts Furthermore independent centres of ossification with hyaline cartilage domination were observed

Endostal formation of bone was scanty in all specimens in the control as well as the anticoagulant treatment groups

HISTOLOGIC ANALYSIS
BY THE LINE SAMPLING METHOD

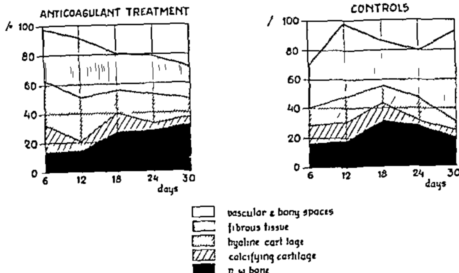



*Fig 7*

Proportions of the different tissue components in the callus of animals whose fracture was induced during anticoagulant treatment and of the controls See text for comments

*Line Sampling*

The results relating to differentiation of the callus tissue by its various components obtained on the basis of the line sampling measurements have been plotted in Fig 7 showing the means of the percentages found for several replicate animals The group of rats whose tibia was fractured while they were already undergoing anticoagulant treatment is compared in the figure to the control group In the controls fibrous tissue accounts for the greatest share in the callus (30 per cent) after 6 days and its contribution remains considerable throughout the period of observation The combined percentage of hyaline cartilage and calcifying cartilage is virtually unchanged (about 25 per cent) during the first 18 days and decreases in the final stage of bone repair The contribution of new bone is seen to increase during the period up to 18 days after which its gradual decrease is noted paralleling the decrease of calcifying cartilage At 6 days in the anticoagulant treatment group hyaline cartilage and calcifying bone present the highest contribution with 31 per cent their share remains dominant up to 18 days (28 per



*Fig 8*

Autoradiographs made with the aid of radioactive phosphorus of the callus of animals whose fracture had been induced during anticoagulant treatment 12 18 and 24 days after the fracture Accumulation of phosphorus in the initial stage in the area of the periosteal collar is clearly seen Later the highest deposit was observed in the centre of the callus

cent) and the subsequent decrease of the cartilage components is seen in this group too The share of new bone in the entire callus shows a gradual increase throughout the period of observation At 18 days closely equal proportions of the different components are seen *in both* groups

## *Autoradiographic and Microradiographic Changes*

The deposition of minerals as demonstrated by the $P^{32}$ phosphate at 6 and 12 days was subperiosteal in the collar At 18 days the highest uptake was seen *to be mineral reaction bands on a level with the frag*ment ends of the fractured bone In the anticoagulant treatment groups the uptake was found to be greater than in the control group At 24 and 30 days the highest uptake was seen still closer to the centre of the fracture area though in less strength than at the earlier times (Fig 8)

At microradiographic examination 6 days after the fracture incipient subperiosteal mineralization was seen in the region of the collar It spread from there to the central callus area At the same time in in



*Fig 9*

Microradiographs of the callus made of specimens from the same animals as in Fig 8 —The mineralization starts at a great distance from the ends of the fragments proceeding at lesser strength towards the central area of the fracture At the points where strong P uptake is seen (Fig 8) the microradiograph reveals incipient mineralization

crease in strength of the mineralization in the collar could be noted However the density of old bone was not attained during the entire period of observation At a later stage mineralization of different degrees was seen in the specimens dense bone trabeculae in the collar area and reticular less strongly mineralized tissue more centrally in the callus area In the anticoagulant treatment group the initial stage of mineralization was consistent with that in the control group but greatly different degrees of mineralization could be observed later at different points of the large callus in this group (Fig 9)

## DISCUSSION

Roentgenologic examination revealed distinct differences between *the different test groups in size and structure of the callus It could* be demonstrated by planimetry that the area of the callus shadow was about twice as large in the case of the animals subjected to anticoagulant treatment as in the control series Considering the entire volume of the callus the estimate can be made that the callus in the anticoagulant treatment group was about seven times the size of that in the controls The changes in callus size were most distinct with the animals

whose fracture had been produced while they were being administered anticoagulant, but it is an interesting observation that anticoagulant treatment instituted at a later time also results in a large callus formation. Measurements of the roentgenographs revealed that the new bone extended to a greater distance from the ends of the bone fragments in the anticoagulant treatment group than in the controls. This is obviously due to the fact that the periosteum is detached over a wider area in the animals of the test groups proper than in the controls. This phenomenon could also be seen at histologic examination.

In the roentgenographs radiolucent spots and cyst-like changes were observable in the animals subjected to anticoagulant treatment. Similar radiolucency has been observed with haemophiliacs, who often present considerable osseous changes (*Crock & Bony* 1960). In haemophilic persons these changes are considered to be caused by continuous periosteal and cortical haemorrhages (*Ghormley & Clegg* 1948). The radiolucent spots in the callus of the animals under anticoagulant treatment, too, are evidently due to persistent minor haemorrhages in the fracture area. These effusions of blood cause resorption of new bone trabeculae, which later results in the formation of cavities.

Both in the standard roentgenographs and in the microradiographic preparations the observation was made in all groups that the formation of new bone started at a great distance from the ends of the bone fragments, at the point where the periosteum could be seen histologically to have become detached from the bone. This is consistent with earlier reports (*Urist & McLean* 1941, *Ham & Harris* 1956). Subsequently the mineralization of the callus moved gradually closer to the centre of the callus.

A notable observation in the present study was that of the abundant occurrence of cartilaginous tissue in the callus of the anticoagulant-treated animals. *Ham & Harris* (1956) have demonstrated in their studies concerning normal bone repair that the periosteum plays a decisive role in callus formation: immediately after the fracture very strong proliferation of the two osteogenous layers of the periosteum takes place and it gradually builds a bridge from fragment to fragment. At points where the osteogenous cells happen to grow in well vascularized surroundings they change into osteoblasts, while they become chondroblasts at points where the vascularization is less abundant. Cartilaginous tissue is thus a normal occurrence in the callus.

Direct ossification only occurs in the places where the vascularization is optimal. In other places the calcification of the cartilaginous tissue

is closely dependent on the penetration of new blood vessels into the callus (*Gothman* 1962) The abundant occurrence of cartilaginous tissue seen in the callus in the animals subjected to anticoagulant treatment and the slower maturation of the callus are obviously explainable on the basis of these observations As a result of the anticoagulant treatment an extensive fracture haematoma can be observed and also far going detachment of the periosteum along the diaphyses These circumstances seem to induce powerful osteogenic activity which leads to the formation of a large sized callus in the fracture area Since the osteogenic cells which even normally display lively growth tend to outgrow the capillaries it appears reasonable to assume that the vascularization in this large callus mass already remains deficient at an early stage As a consequence of the poor vascularization a considerable part of the osteogenous cells is then converted to cartilage The observations are clearly in support of *Harris & Ham*'s (1956) contention that the fracture haematoma appears to be more of an obstacle than anything else to the growth and fusion of the collars of osteogenic tissue that bring about union

The high percentage of cartilaginous tissue and of cartilage in the process of calcification (51 per cent) in the callus during the initial stage of bone repair was clearly demonstrated in the anticoagulant treatment group by the line sampling measurements The differences between this group and the controls diminished in the course of the period of observation and very nearly the same composition of the callus was seen at 18 days that is at the time when most fractures appeared clinically stable Subsequently in the control series the share of new bone of calcifying cartilage and of cartilage decreased as an obvious consequence of the remodelling of the callus In the anticoagulant treatment group however the repair process continued further also after a period of 18 days and this too can be considered a sign of immaturity —As regards the method of line sampling analysis which was first applied by *Koskinen* (1959) as a means of studying the callus formation it may be noted that the present modification with a number of transects examined in each cut presented a clear and perspicuous picture of the occurrence of the tissue components in the entire callus area

The autoradiographic and microradiographic examinations yielded results in support of the observations made in the roentgenologic histologic and histoquantitative studies It could be clearly demonstrated both in the anticoagulation treatment group and in the control group

FRACTURE REPAIR

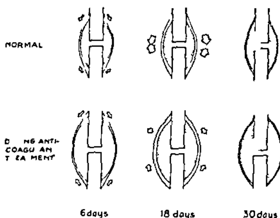



*Fig. 10*

*Schematic diagram illustrating the normal repair of a fracture and that during* anticoagulant treatment.—Normally the osteogenic activity of the periosteum creates an external callus. Ossification proceeds in principle accordingly as the callus is vascularized. The large fracture haematoma produced as a result of anticoagulant treatment leads to a large sized callus, which needs a longer time to become vascularized. As a consequence the bony consolidation, which takes place normally in other respects, is delayed.

that the process of ossification had its start in the periosteal collar moving continuously closer to the centre of the fracture area in the course of time.

On the strength of the findings and inferences presented in the foregoing a schematic characterization of the stages of progress occurring in the anticoagulant treatment group and in the control group is possible (Fig. 10).

*Stinchfield et al.* were the first to note the detrimental effect of anticoagulant treatment on the repair of experimental fractures. This effect was attributed either to deficient fibrin formation in the fracture haematoma or to histotoxic action. Neither conjecture finds support in the present observations. The differences in the callus found in the present study to have been produced by anticoagulant treatment are due, in the writers' opinion, to the extensive fracture haematoma, to the great size of the callus and to its poor vascularization. Consistent with the present findings is the abundance of cartilaginous tissue in the callus as a consequence of heparin treatment observed by *Minola et al.*

*Stinchfield et al.* advise caution in the administration of anticoagu-

lant agents to fracture patients. On the strength of their experimental observations *Minola et al.* did not consider anticoagulant treatment detrimental to the bone repair process. Although the changes established in the present study do not justify inferences in respect of clinical work, the observation that prolonged anticoagulant treatment produces distinct changes in the callus at the site of the fracture in experimental animals should be kept in mind in clinical practice.

## SUMMARY

The purpose of the study was to clarify the effect of prolonged anticoagulant treatment on the healing of fractures of the tibia. Sintrom® (Geigy) was administered as an anticoagulant agent by intramuscular injection to 45 rats with fractured tibia. The fracture was induced in one group while the animals were being given anticoagulant treatment, whereas such treatment was not started in the other group until the third day after the fracture. In a control group of 25 animals similar fractures were induced but no treatment applied. The period of observation was 6–30 days.

The *roentgenographic examination* revealed a callus of larger size and looser structure in the anticoagulant treatment groups than in the control group. Even cyst-like changes were encountered. *Planimetric study* showed that the callus in the anticoagulant treatment group was twice the size of that in the control group. *Histologic examination* demonstrated that ossification occurred in a normal manner in all groups proceeding from the collar mainly subperiosteally, but in the anticoagulant treatment group the callus was found to be larger and more strongly cartilage dominated. The abundant occurrence of cartilaginous tissue seems to be due to poor vascularization. Reshaping of the callus had already commenced in the control group 18 days after the fracture but had not yet started in the anticoagulant treatment group by the 30th day. This inference is also supported by the histoquantitative results yielded by the *line sampling method*. The *autoradiographic and microradiographic studies* gave evidence to the effect that the process of mineralization progressed from the periosteal collar towards the centre of the fracture in essentially identical manner in all test groups.

## RÉSUMÉ

Le but de l'étude était de clarifier l'effet d'un traitement anticoagulant prolongé sur la guérison des fractures du tibia. Sintrom® (Geigy)

a été administré comme agent anticoagulant par injection intramusculaire à 45 rats ayant un tibia fracturé. La fracture a été provoquée dans un groupe alors que les animaux étaient soumis à un traitement anticoagulant, tandis que le traitement ne fut entrepris dans l'autre groupe que le 3ème jour après la fracture. Dans un groupe de contrôle de 25 animaux une fracture similaire fut provoquée mais sans appliquer de traitement. La période d'observation a été de 6 à 30 jours.

*L'examen radiographique* révéla un cal de plus grande dimension et de structure plus lâche dans le groupe traité à l'anticoagulant que dans le groupe de contrôle. On a même observé des modifications ressemblant à un kyste. Une *étude planimétrique* montra que dans le groupe auquel a été administré le traitement anticoagulant, le cal a deux fois la grandeur de celui du groupe de contrôle. Un *examen histologique* a démontré que l'ossification se fait de manière normale dans tous les groupes progressant du col principalement subpériostalement. Toutefois, dans le groupe traité par anticoagulant le cal était plus grand et plus fortement cartilagineux. La présence d'un abondant tissu cartilagineux semble être due à une pauvre vascularisation. La formation du cal commence dans le groupe de contrôle déjà 18 jours après la fracture, mais n'avait pas encore commencé dans le groupe traité au coagulant le 30ème jour. Cette constatation est aussi appuyée par les résultats histoquantitatifs obtenus par la *méthode de la ligne de suture*. Les *études autoradiographiques et microradiographiques* ont rendu évident que le processus de minéralisation progresse du périoste du col vers le centre de la fracture d'une manière essentiellement identique dans tous les groupes d'essai.

## ZUSAMMENFASSUNG

Der Zweck dieser Untersuchung war es, die Wirkung einer langdauernden antikoagulierenden Behandlung auf die Heilung von Tibiabrüchen aufzuklären. Sintrom® (Geigy) wurde als Antikoagulant mittels intramuskulärer Injektion an 45 Ratten mit gebrochener Tibia verabreicht. In einer Gruppe wurde der Bruch erzeugt, während die Tiere antikoagulierende Behandlung erhielten, während in einer anderen Gruppe diese Behandlung nicht vor dem dritten Tage nach dem Bruche eingeleitet wurde. In einer Kontrollgruppe von 25 Tieren wurde ein gleicher Bruch erzeugt, aber keinerlei Behandlung gegeben. Die Beobachtungszeit war 6–30 Tage.

Die *röntgenographische Untersuchung* zeigte einen ausgedehnteren Kallus mit loserer Struktur in der mit Antikoagulantia behandelten

Gruppe als er in der Kontrollgruppe zu finden war Sogar zystenartige Veränderungen wurden angetroffen

*Planimetrische Studien* erwiesen dass der Kallus in der Antikoagulantgruppe doppelt so gross als der in der Kontrollgruppe war

*Die histologische Untersuchung* demonstrierte dass die Verknocherung in allen Gruppen auf normale Weise vor sich ging indem sie vom Kragen hauptsächlich subperiostal fortschritt aber in der Antikoagulantgruppe war der Kallus ausgedehnter und mehr von Knorpelbildung beherrscht Das reichliche Vorkommen von Knorpelgewebe scheint mit der schlechten Blutgefassversorgung im Zusammenhang zu stehen Neuformung des Kallus begann in der Kontrollgruppe bereits 18 Tage nach dem Bruche wahrend sie in der Antikoagulantgruppe noch nicht nach 30 Tagen begonnen hatte Diese Beobachtung wird auch durch die Resultate die sich aus der *Line Sampling Methode* ergeben unterstutzt Die *autorontgenographischen und mikrorontgenographischen Studien* bezeugten dass der Prozess der Mineralisierung vom periostalen Kragen gegen das Zentrum des Bruches bei allen Untersuchungsgruppen wesentlich in gleicher Weise vor sich ging

## REFERENCES


*Aulisa B* I azi ne degli anticoagulanti sul proces di formazi ne e di consolidazione del callo osseo Riv Patol Clin *15* 820–834 1960

*Crock H V & Bone V* The management of orthopaedic problems in haemophiliacs A review of 2 ca es Brit J Surg *48* 8–15 1960

*Ghormley R K & Clagg R S* Bone and joint changes in hemophilia With rep rt of cases of so-called p eudotumor J Bone Jt Surg *30* A 589–600 1948

*Göthman L* Vascular reactions in experimental fractures Microangiographic and radioisotope studies Acta chir Scandinav Suppl 284 1961

*Ham A W & Harris W R* Repair and transplantation of b ne In The biochemistry and physiology f b ne Ed G H Bourne Academic Press Inc New York 1956

*Harris W R & Ham A W* The mechanism of nutrition in b ne and how it affects its structure repair and fate on tran plantati n In Ciba F undati n Symposium on b ne structure and metabolism Ed C E W Wolstenh lme J & A Churchill Ltd., Lond n 19 6

*K skinen E V S* The repair f experimental fractures under the action f growth horm ne thyrotr pin and c rti one A ti ue anal tic roentgen l gic and autora liographic study Ann Chir G naec Fenn Suppl 90 1959

*Lison L* Alcian blue 8 G with chloratine fa t red 5 B Technic f r selective staining f muc p lysacchari les Stain Technol 9 131 138 1954

*Min la C C Vasta A C & Cranalo F* F rmaci anticoagulanti e fibrin litici nell evoluzi ne delle fratture periment li Ra It Chir Med 137–151 19 8

*Owren P A* Thrombotest—a new method for controlling anticoagulant therapy Lancet *II* 754–758 1959
*Solonen K A* Prophylactic anticoagulant therapy in the treatment of lower limb fractures Acta orthop Scandinav *33* 329–341 1963
*Steedman H F* Alcian blue 8 GS new stain for mucin Quart J micr Sci *91* 477–479 1950
*Stinchfield F R Sandaran B & Samilson R* Effect of anticoagulant therapy on bone repair J Bone Jt Surg *38 A* 270–282 1956
*Uotila U* Einfaches Verfahren zur Bestimmung des Volumens und Gewichts des Schilddrusenkolloids Acta Soc Med Duodecim Ser A *23* 77–83 1940
*Uotila U & Kannas O* Quantitative histological method of determining the proportions of the principal components of thyroid tissue Acta endocr (Kbh) *11* 49 60 1952
*Urist M R & McLean F C* Calcification in the callus in healing fractures in normal rats J Bone Jt Surg *23* 1–15 1941

Acta orthop Scandinav XXXV 39–50 1964

From the Department of Orthopaedics Karolinska Institutet Stockholm
(Head Sten Friberg)

# RIGIDITY OF IMMOBILIZATION OF OBLIQUE FRACTURES

By

Olov Lindahl

The present study of the rigidity of immobilization of oblique diaphysis fractures is a sequel to a corresponding one on transverse diaphysis fractures (*Lindahl* 1962) From the mechanical standpoint there are many similarities in the immobilization of these two types of fractures but there are also a number of differences among which are the following

1) Displacement of the ends of an oblique fracture usually occurs in the axial direction in a transverse fracture however there is no such movement after the fragments have been set

2) There is a marked difference in the ease with which an oblique fracture can be bent in different directions Bending in the plane that is perpendicular to the plane of fracture sets up a compression whereas bending in any other direction will tend to cause a rotational displacement between the fracture surfaces Transverse fractures are symmetric in this respect

3) There are many more ways of immobilizing an oblique fracture than a transverse fracture—for instance screws and cerclages may be used

4) The use of screws presents a particular problem namely what direction of the screws will provide the greatest rigidity Since however similarities between the two types of fractures predominate over the dissimilarities the reader is referred to the earlier paper which deals with the problems and method The present article is concerned chiefly with the details of the method that differ from those of the previous study

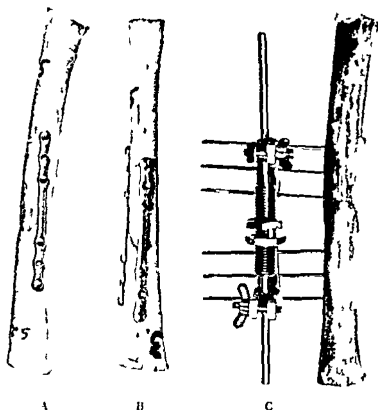



*Fig. 1*
Immobilization of fractured femoral shaft.
A, one Sherman plate; B, two Sherman plates; C, Hoffmann instrument.

## MATERIAL

Fresh femoral shafts from autopsies were used after they had been freed from soft tissues and the marrow had been washed out with hot water. The shaft was sawn in two by an oblique cut at an angle of 30° to the axis. The bone was sawn in a downward and backward direction so that the surface of fracture was perpendicular to the sagittal plane. The following methods of immobilization were used.

(1) Three cerclage wires (one millimetre thick and secured with a surgical knot); (2) one no. 2 Sherman plate (of the heavier type) with 6 holes; (3) two Sherman plates of the same type; (4) Hoffmann instrument; (5) three osteosutures (3 mm. drill holes, one millimetre wire secured with a surgical knot); (6) two screws perpendicular to the shaft axis; (7) two screws perpendicular to the plane of fracture; (8) three




*Fig 2*
Immobilization of fractured femoral shaft
A three osteosutures B two screws C three screws

screws perpendicular to the shaft axis (9) three staples (10) Küntscher nails (Figs 1 and 2)

The plates screws and staples were of Vitallium and the nails Hoffmann instrument and wires of stainless steel The cerclage wires were placed symmetrically over the fracture The single plate was placed on the lateral aspect of the bone and when two plates were used the other was placed on the anterior aspect the Hoffmann instrument was placed on the lateral aspect the staples and osteosutures were placed on the medial lateral and anterior sides and the screws were inserted from the anterior side Surgical instruments were employed and the various immobilizations could be performed better than at an actual surgical operation Since the stability was tested in more directions than for the transverse fractures in the previous study duplicate specimens were usually made for each method of immobilization a total of 14 specimens were used

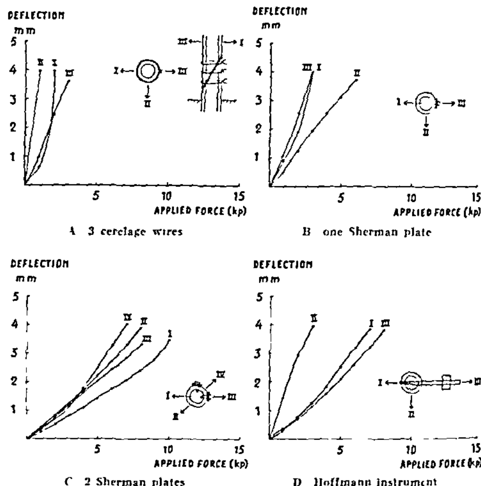
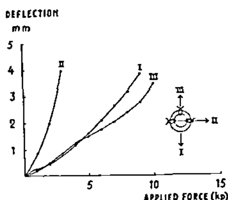



*Fig 3*

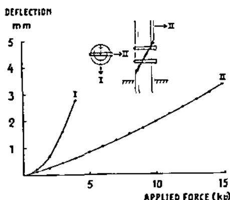
A–D Relationship between bending force applied at a point 10 cm from the mid point of the oblique fracture and the deflection at the point of application The directions of loading are indicated in the plan

## METHOD

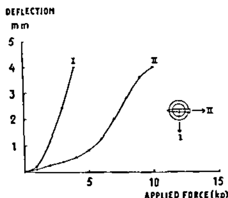
The method was the same as that in the foregoing study (*Lindahl* 1962 Fig 1 p 239) except that the specimen was not subjected to axial compression The reason for this difference is that the oblique fractures were usually more difficult to immobilize and that even when the load was small there was a tendency for rotational displacement in the surface of fracture As a result the axial compressive force gave rise to a bending moment which was added to the applied bending moment this complicated the interpretation of the results As in the previous



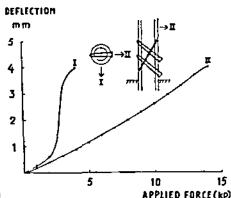

A 3 osteosutures




B 2 screws perpendicular to the shaft




C 3 screws perpendicular to the shaft




D 2 screws perpendicular to the plane of fracture

*Fig* 4

A–D As for Fig 3 A–D

study the torsional rigidity was tested and in addition the resistance to compression So as not to cause permanent deformation of the immobilizing device or damage to the bone the bending tests were discontinued at a deflexion of 4 mm and in the torsion experiments at an angle of rotation of 3° This usually enabled the specimens to be used for more than one test The compressive strength was tested up to 3 mm deformation or a load of 180 kp[1] The movement was recorded after the load had been applied for 10 seconds The tests were performed at the Swedish National Testing Laboratories

[1] One kilopond = 9·80665 newtons = 2·2046 pounds weight

DEFLECTION
mm
10
5
3 CERCLAGES
HOFFMANN INST
1 PLATE
3 OSTEOSUTURES
3 SCREWS 1
2 SCREWS 2
2 SCREWS 1
2 PLATES
INTACT FEMUR
5
10
APPLIED FORCE (kp)

) 1 PERPENDICULAR TO THE FEMUR SHAFT
2 " " " FRACTURE SURFACE

*Fig. 5*

Comparison between different methods of osteosynthesis. The lowest recorded values have been taken as representative of each method.

## RESULTS

It is seen from Figs. 2 and 3 A–D that the rigidity varied widely with the direction of the applied tensile force and that it was usually lowest for the direction in which there was a rotatory displacement between the fracture surfaces. The rigidity was extremely low in this direction. Attempts to immobilize an oblique fracture with three staples were unsuccessful, the reason being that in the oblique fracture, in contrast

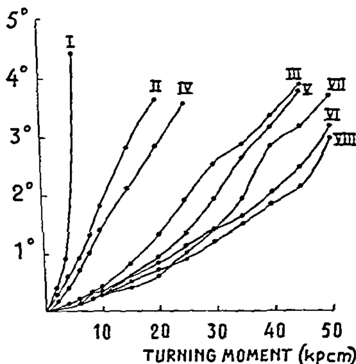



*Fig 8*

Comparison between methods of immobilization for oblique fractures of the femur showing the relationship between the turning moment and the resulting angle of rotation recorded for (I) 3 cerclage wires (II) one Sherman plate (III) 2 Sherman plates (IV) Hoffmann instrument, (V) 3 osteosutures (VI) 2 screws perpendicular to the shaft (VII) 2 screws perpendicular to the plane of fracture, and (VIII) 2 screws perpendicular to the shaft.

to bending in different planes to rotation and to compression was the same for small loads whether two or three screws were used and whether they were inserted perpendicular to the shaft axis or to the fracture surface For bending in the plane of the fracture and loading over 50 kpcm however the rigidity was lower for screws perpendicular to the surface of fracture than for those perpendicular to the shaft axis For compressions over 150 kp the direction perpendicular to the fracture surface was the less satisfactory

A mechanical analysis and tests on models showed that the screws

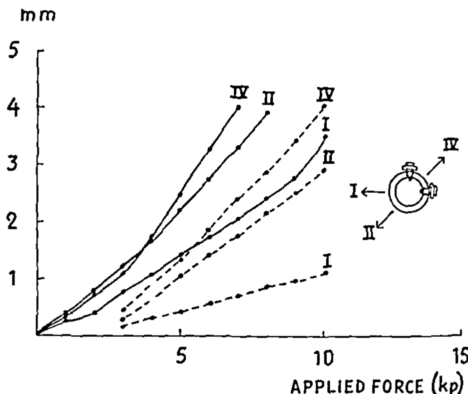



*Fig 7*
As for Fig 6 but with 2 Sherman plates

Comparison of transverse and oblique fractures as regards the *rigidity achieved with the same means (one or two plates) showed that* the results were slightly poorer for the oblique fracture (Figs 6 and 7). The reason for this is probably that a transverse fracture cannot be compressed whereas this is possible in the case of an oblique fracture in which the fracture surfaces can slide against one another.

In general there is an association between the rigidity for torsion and bending but it should be noted that screws provided greater rigidity to torsion than plates (Fig 8). As regards the compressive strength (Fig 9) the Hoffmann instrument offered extremely little resistance to pressure, this is in accordance with clinical experience that this method is unsuitable for immobilization of oblique fractures. The greatest compressive strength was provided by two plates but screws gave as great rigidity for loads up to 80 kp. Comparison of the rigidity obtained with different numbers and directions of screws shows that the resistance

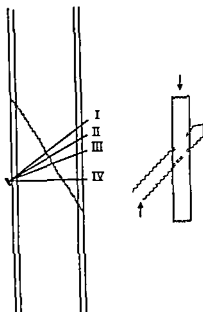



*Fig 10*

Examples of various directions of screwing in immobilization of oblique fractures by means of screws (I) forming a small angle to the shaft (II) at right angles to the fracture surface (III) intermediate position and (IV) at right angles to the shaft

internal immobilization is demonstrated and discussed Although there are several ways of immobilizing oblique fractures and although the greater area of the fracture surfaces should provide better immobilization it is evident from the findings of the present study that with internal immobilization the rigidity was poorer for oblique than for transverse fractures The rigidity was particularly low for forces applied in such a direction that the surfaces of fracture rotated against one another

In both studies the fracture surfaces were fairly even since they were sawn In natural fractures the surfaces are often uneven or jagged Provided that an accurate reduction is effected the rigidity due to the form of the fracture surfaces will often be considerably greater than was the case in these studies In spite of this the rigidity obtained cannot be regarded as satisfactory One essential reason for the application of the open fracture treatment is the common belief that with it the immobilization would be practically complete The object of the operation is not only to secure coaptation of fracture ends but rather to prevent them from moving in relation to one another This object can

not be considered to be achieved with the methods at present used and further research would seem to be indicated with the purpose of devising a really rigid method of internal immobilization

## SUMMARY

Experiments have been performed to examine the rigidity of different methods for the internal immobilization of oblique fractures—Sherman plates staples Kuntscher nails Hoffmann instruments screws osteosutures and cerclages The experiments were performed on femur shafts and the rigidity was tested by bending in different planes by torsion and compression For all the methods the rigidity was unsatisfactory from a purely mechanical standpoint The best immobilization was obtained with two Sherman plates placed perpendicular to each other

## RESUME

Des experiences ont ete pratiquees pour examiner la rigidite de différentes méthodes d immobilization interne de fractures obliques – plaques et crampons de Sherman clous de Kuntscher instruments de Hoffmann vis osteosutures et cerclages Les experiences ont ete effectuees sur des corps de femur et la rigidite a èté controlée pas des essais de flexion dans differents plans de torsion et de compression Pour toutes les methodes la rigidite etait insatisfaisante consideree d un point de vue purement mecanique La meillure immobilisation a ete obtenue au moyen de deux plaques Sherman placees perpendiculairement l une a l autre

## ZUSAMMENFASSUNG

Experimente wurden ausgefuhrt um die Festigkeit von verschiedenen Methoden der internen Ruhigstellung von Schrägbruchen zu untersuchen – Sherman Platten Haspen Kuntscher Nägel Hoffmann Instrumente Schrauben Knochensuturen and Cerklagen Die Versuche wurden an Femurschaften ausgefuhrt und die Festigkeit wurde mittels Beugung in verschiedenen Ebenen unter Torsion und Kompression gepruft Bei allen Methoden war die Stabilitet von rein mechanischen Standpunkt unbefriedigend Die beste Ruhigstellung wurde mittels zwei Sherman Platten die senkrecht zueinander angelegt waren erreicht

## REFERENCE

*Lindahl O* Acta orthop Scandinav 32 237 246 1962

Acta orthop. Scandinav. XXXV, 51–58, 1964

From the Orthopaedic Clinic, Lund (Head: Prof. G. Wiberg.)

# OVERGROWTH FOLLOWING FRACTURE OF HUMERUS IN CHILDREN

By

H. Emnéus and O. Hedström

Fracture of the femur in children is followed by overgrowth of the bone provided the epiphyseal cartilage is intact (*Truesdell* 1921, *David* 1924, *Levander* 1929, *Blomkvist & Rudström* 1943, *Blount* 1952, 1954, *Trueta* 1957, *Greville et al.* 1957).

Such overgrowth has long been known in osteomyelitis not involving the epiphyseal cartilage (*Stanley* 1849, *Langenbeck* 1869, *Speed* 1923, *Trueta* 1955).

The phenomenon has received extensive attention and it is now widely accepted that the overgrowth is due to increased blood supply to the epiphyseal cartilage.

Attempts have been made to reproduce the phenomenon in laboratory animals. It has proved difficult to study the longitudinal bone growth in such small animals: they grow too quickly and the period of growth is too short. But the same tendency can be observed though the overgrowth is not so regular or so marked as in human beings (*Ollier* 1867, *Wu & Mu Miltner* 1937, *Brodin* 1955 and others). In larger animals (goats and dogs), however, the course resembles that in man (*Bisgaard & Bisgaard* 1935, *Greville & Jones* 1957 and others).

Though it is generally accepted that the overgrowth is due to increased circulation, our knowledge of the actual stimulus is still vague.

It is but natural that these observations gave rise to hopes of accelerating longitudinal bone growth of a shortened leg after poliomyelitis, for example. Implantation of various sorts of material has been tried with varying success. Thus *Pease et al.* (1952) inserted ivory pegs in the metaphysis of patients with a shortened leg after poliomyelitis and noted a certain acceleration of growth. *Trueta* (1953) and *Stahl* (1957) plugged the marrow cavity of the tibia of the shortened leg; they loosened the periosteum and then cut a window in the corticalis through

TABLE 1

*Overgrowth of Humerus Following Fractures at Different Levels of the Bone in Children. The Patients' Ages at the Time of Accident Ranged between 2 and 13 Years. 49 Patients Reviewed after an Interval of 1½ to 9 Years, the Remaining 21 Subjected to Repeated Examinations until 3 Years after the Accident*

| | No |
|---|---|
| 1 *Supracondylar Fractures* | |
| 0 overgrowth | 2 |
| 2–5 mm overgrowth | 8 |
| 6–9 mm overgrowth | 18 |
| 10–17 mm overgrowth | 16 |
| | 44 |
| 2 *Diaphyseal Fractures* | |
| 0 overgrowth | 3 |
| –10 mm overgrowth | 8 |
| | 11 |
| 3 *Collum Chirurgicum Fractures* | |
| 0 overgrowth | 2 |
| 2–5 mm overgrowth | 3 |
| 6–20 mm overgrowth | 10 |
| | 15 |

Overgrowth was observed in 63 out of 70 cases.
Overgrowth was not found to vary with level of the fracture.

which they packed the marrow cavity with bone chips. They thus created an injury resembling a fracture as well as obstruction of the nutritional artery. This procedure also produced a certain degree of overgrowth.

*Janes & Musgrove* (1950) and *Hiertonn* (1961) established arteriovenous anastomoses in patients who had had poliomyelitis and the overgrowth they noted was astonishing. *Hiertonn's* clinical observations may be regarded as the strongest evidence that hyperemia is the cause of the overgrowth. All previous clinical series have consisted of mid-diaphyseal fractures (*David* 1924, *Levander* 1929, *Blomquist & Rudström* 1943, *Trueta* 1953). Since Trueta, for example, thought that it was obstruction of the nutritional artery that was responsible for the development of collaterals with consequent hyperemia of the epiphysis, we considered it of interest to study metaphyseal fractures. For this purpose we selected the humerus, in which typical fractures may be

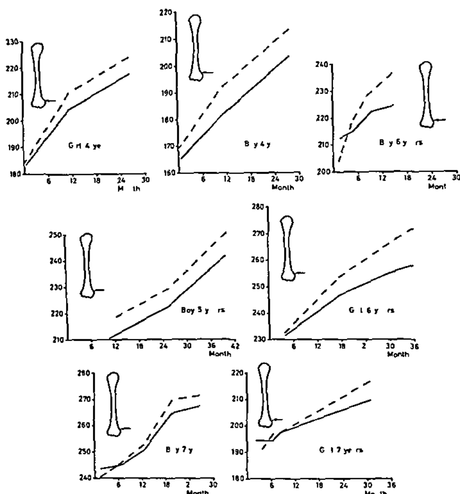



*Fig. 1.*
Supracondylar fractures.
- - - Injured side ——— Healthy side

seen near the epiphysis above the condyles as well as through the surgical neck. In supracondylar fractures of the humerus, for example, the blood supply via the nutritional artery to the proximal epiphysis is intact and this epiphysis accounts for about three fourths of the longitudinal growth of the bone.

Part of the present material was reported previously by *Emneus* (1957) and by *Emneus & Wiberg* (1957) in an earlier investigation in which the purposes was also to find answers to the following questions

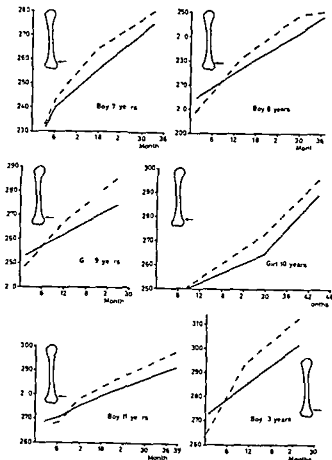


*Fig. 9*
Supracondylar fractures
- - - Injured side ——— Healthy side

1. How often can overgrowth be demonstrated after fracture of the growing bone?
2. Does overgrowth vary with the level of the fracture?
3. When does overgrowth begin and how long does it continue?

The material now consists of 70 fractures including 63 with overgrowth (Table 1).

Of the cases given in Table 1, 21 were followed up for 3 years after the accident with repeated measurement of the roentgenographic length of the bone. The material is small but it should be mentioned that it is difficult to get children to present themselves for regular

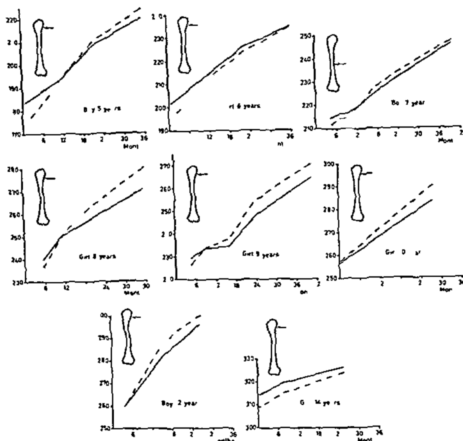


*Fig 3*

Mid diaphyseal and surgical neck fractures

– – – – – – Injured side ———— Healthy side

follow up when they are symptomfree and healthy This explains why the number of cases in which the growth in length could be measured repeatedly was relatively small

The measurements were made in accordance with a roentgen orthodiagraphic technique elaborated by *Norman* (1955) The mean error of the method is said to be about 1 mm

Figs 1–3 summarize the 21 cases (11 boys and 10 girls) Of the fractures 14 were left sided and 7 were right sided The rate of growth can be read from the diagram The curves do not show when accelerated growth began but such information should be obtainable from a series studied at shorter intervals The curves do however show that stimula

tion of growth continued for 12 months in 6 cases, for 18 months in 10 and still longer in 4. Only in one case was no difference found between the rate of growth of the fractured bone and the unfractured fellow bone. The boy was 5 years old (Fig. 1). Two explanations for this lack of difference may be considered: No growth had occurred, or it had occurred and discontinued within the 10 months before the first measurements had been taken. If the latter explanation be accepted it would seem justified to postulate that overgrowth following fracture of the humerus in children is a regular occurrence.

The increased rate of growth of the humerus following proximal fractures was not found to differ significantly from that following distal fractures. Since the proximal epiphysis is responsible for three fourths of the growth in length of the bone, this lack of difference is astonishing and suggests either that the proximal epiphysis is stimulated by a distal fracture or that the rate of growth of the normally slowly growing distal epiphysis increases markedly. An investigation of this point is in progress.

## SUMMARY

It has long been known that the rate of growth of a shaft bone after a fracture is temporarily increased. The phenomenon has been studied in human beings and in animals, and especially in the lower limbs. In the present investigation, in which the material consisted of humerus fractures in 70 children, roentgenographic measurements were made on one later occasion in 49 and repeatedly in 21. The purpose was to assess the frequency of such overgrowth in length, its duration and its variation, if any, with the level of the fracture. Increased rate of growth was found in 63 cases. In 16 of 21 cases re-examined repeatedly the increased rate of growth ceased after 18 months and in 4 it continued still longer. The increased rate of growth was not found to vary with the level of the fracture.

## RÉSUMÉ

On sait depuis longtemps que le taux de croissance d'un corps osseux est temporairement accru après une fracture. Ce phénomène a été étudié chez l'être humain et les animaux, en particulier pour les extrémités inférieures. Dans la présente enquête, où le matériel d'observation représentait des fractures de l'humérus chez 70 enfants, des mensurations radiographiques ont été effectuées à une occasion ultérieure dans 49 cas et répétées dans 21 cas. Le but de l'examen était d'établir

la frequence d une telle supercroissance en longueur sa duree et sa variation s il y en avait par rapport au niveau de la fracture On a trouvé un taux accru de croissance dans 63 cas Dans 16 des 21 cas reexamines à plusieurs refrises la croissance accrue s est arretee au bout de 18 mois et dans 4 elle s est poursuivie encore plus longtemps Il n a pas ete constate que le taux de croissance accrue varie suivant le niveau de la fracture

## ZUSAMMENFASSUNG

Die Tatsache dass die Wachstumsgeschwindigkeit eines Rohren knochens nach einem Bruch zeitweilig zunimmt ist seit langem bekannt Diese Erscheinung ist beim Menschen und beim Tiere besonders an den unteren Gliedmassen untersucht worden Bei der vorliegenden Unter suchung in der das Material aus 70 kindlichen Humerusbruchen bestand wurden spatere rontgenologische Messungen einmal in 49 und mehrere Male in 21 Fallen vorgenommen Man bezweckte damit die Haufigkeit des übermassigen Langenwachstums seine Dauer und even tuelle Verschiedenheit unter Berucksichtigung der Hohe des Bruches festzustellen Eine Beschleunigung des Langenwachstums wurde in 63 Fallen gefunden Bei 16 von 21 Fallen die wiederholt untersucht wur den horte die Wachstumsbeschleunigung nach 18 Monaten auf und bei 4 setzte sie noch daruber hinaus fort Es wurde gefunden dass die Wachstumsbeschleunigung nicht von der Lokalisation des Bruches beinflusst wurde

## REFERENCES

*Bisgaard J D* Longitudinal Overgrowth of Long Bones with Special Reference to Fractures Surg Gynec Obstet *LXII* 823 1936

*Bisgaard J D & Bisgaard M E* Longitudinal Growth of Long Bones Arch Surg *XXXI* 6 8 1935

*Blomqvist E & Rudstrom P* Ueber Femurfrakturen bei Kindern unter besonderer Berucksichtigung des gesteigerten Langenwachstums Acta chir Scandinav *LXXXVIII* 267 288 1943

*Blount W P & Zeier F* Control of Bone Length J A M A *148* 451 457 1952

*Blount W P* Fractures in Children Baltimore Williams & Wilkins 1954

*Brodin H* Longitudinal Bone Growth The Nutrition of the Epiphyseal Cartilages and the Local Blood Supply Acta orthop Scandinav suppl 20 1955

*David V C* Shortening and Compensatory Overgrowth Following Fractures of the Femur in Children Arch Surg *IX* 438 1924

*Emneus H* Stimulation of Growth in Length After Humerus Fractures in Children Proc Nord Orthop Forenings 28th Assembl in Helsingfors 1956 (ed ) Acta orth Scandinav XXVI 4 3 4 326 19

*Emneus H & Wiberg C* Influence of Fracture on Growth in Length of Shaft Bones Septieme Congrés de la Sociéte Internationale de Chirurgie Orthopedique et de Traumatologie Barcelone 16–21 septembre 1957 pp 505–509

*Greville N R & Janus J M* An Experimental Study of Overgrowth After Fractures Surg Gynec Obstet *105* 717–721 1957

*Hierlonn T* Arteriovenous Anastomoses and Acceleration of Bone Growth Acta orthop Scandinav *31* 25 1961

*Janes J M & Musgrove J E* Effect of Arteriovenous Fistula on Growth of Bone Surg Clin N Amer *30* 1191–1200 1950

*Lacroix P* The Organization of Bones Churchill London 1951

*v Langenbeck B* Ueber krankhaftes Langenwachstum der Röhrenknochen und seine Verwertung fur die chirurgische Praxis Berl klin Wschr *6* 265 270 1869

*Leander G* Increased Growth of Long Bones of Lower Extremities after They Have Been Fractured Acta chir Scandinav *65* 5 Suppl 12 p 237 1929

*Norman O* Personal communication 1955

*Ollier L* Traité expérimental et clinique de la régénération des os Tome I Paris p 383 392–396 1867

*Pease C N* Local Stimulation of Growth of Long Bones A Preliminary Report J Bone Jt Surg 34–A 1–24 1952

*Speed K* Growth Problems Following Osteomyelitis of Adolescent Long Bones Surg Gynec Obstet *XXXIV* 469 1922

*Stanley E* A Treatise on Diseases of the Bones London Longman Brown Green and Longmans 1849

*Ståhl F* Plugging of the Marrow Cavity of the Tibia for Stimulating Growth in Length Proceedings of the Nord Orthop Forenings 28th Assembly in Helsingfors June 1956 (ed ) Acta orthop Scandinav XXVI 4 322 324 1957

*Truesdell F D* Ann Surg 74 498–500 1921

*Trueta J* The Influence of the Blood Supply in Controlling Bone Growth Bull Hosp Jt Dis *14* 147–157 1953

*Wu Y K & Miltner L J* Procedure for Stimulation of Longitudinal Growth of Bone an Experimental Study J Bone Jt Surg *19* 909 921 1937

Acta orthop Scandinav XXXV 59 66 1964

From the Clinic for Orthopaedics and Traumatology University of Helsinki
(Head Professor K E Kallio)

# EFFECT OF SCALENOTOMY IN THE SO CALLED SCALENUS ANTICUS SYNDROME

By

ERKKI KALLIO and PENTTI ROKKANEN

Undoubtedly the Scalenus Anticus Syndrome is a rather confusing term It is used for a variety of conditions where the main symptoms are neurovascular disturbances in the upper limb These can be due mainly or partly and secondarily to pressure effect of the scalenus anterior muscle The terms cervical rib or costoclavicular syndrome and even brachialgia are used in this connection They only show the multiplicity of factors involved One thing seems to be common to all these conditions Namely that the main symptoms pain paresthesia and muscular weakness can be cured or markedly relieved by the simple operation of scalenotomy

The purpose of the present investigation is to show the results obtained by scalenotomy in cases where the perplexing condition of the so called scalenus anticus syndrome was diagnosed or strongly suspected Two clinical follow up studies have been published in Finland on this subject (*Ahonen* and *Gylling*)

### *Own Material and the Follow-Up Results*

The present series consists of all the cases where scalenotomy was performed at the Orthopaedic University Clinic during the years 1951–63 The total material is 64 cases The age and sex distribution of the cases will be seen in Table 1

Eight patients are known to be dead but we have had good information from three of them Eight patients did not answer the questionnaire The total material available for follow up study is therefore 51 cases The length of the observation period is described in Table 2

This material was divided into four different groups The first group "excellent consists of those patients who stated that their symp-

were immediately cured by the operation and that the result was permanent. The second group of patients "good" stated that the operation relieved their symptoms markedly immediately and that their condition is much better now than before the operation. The third group of patients "fair" claimed that the operation was worth while and that they got some benefit from it. The fourth group "poor" contains all the patients who stated that the operation was of no value to them. No-one claimed that the operation had aggravated their symptoms or reported any other ill effects from the operation.

TABLE 1

| Age | Female | Male | Total |
|---|---|---|---|
| 70–79 | – | 1 | 1 |
| 60–69 | 3 | 3 | 6 |
| 50–59 | 10 | 14 | 24 |
| 40–49 | 10 | 10 | 20 |
| 30–39 | 5 | 4 | 9 |
| 20–29 | 2 | 2 | 4 |
| | 30 | 34 | 64 |

TABLE 2

| | |
|---|---|
| Follow-up period over 9 years | 7 cases |
| 7–9 years | 3 cases |
| 5–7 years | 9 cases |
| 3–5 years | 10 cases |
| 1–3 years | 20 cases |
| Under 1 year | 2 cases |
| | 51 cases |

The follow up study shows that 35 patients out of 51, that is about *69 per cent, were cured or definitely improved by the small operation.*

What has the exact diagnosis been in these cases? One may say that in those cases where the condition did not improve the diagnosis had not been scalenus anticus syndrome. In cases where the condition was practically cured immediately and permanently the scalenus anticus muscle certainly had something to do with symptoms. Nearly all of the patients in the "excellent" group expressed spontaneously their sincere gratitude to the surgeon. They pointed out that the conservative treatment had been of no value and that the operation produced immediate relief. The results are described in Table 3.

TABLE 3
*The Results*

| | |
|---|---|
| Excellent | 21 cases |
| Good | 14 cases |
| Fair | 5 cases |
| Poor | 11 cases |
| | 51 cases |

In the X ray pictures we did not find any cervical ribs and only one hypertrophic costal process of the seventh cervical vertebra In only 10 per cent of the cases were no degenerative changes to be seen in the cervical spine The main complaint had been pain in the upper extremity The pain radiated often to the fingers and the hand was weak

The objective findings at the clinical examination were in the following order of frequency tenderness to palpation at the supraclavicular region especially at the site of the scalenus anterior muscle weakness in the grip and squeezing power of the hand dropping of the shoulder at the side of the affection and sensory changes in the hand

Particularly in the excellent group the patients could often find some position in the upper limb where the symptoms were relieved Carrying heavy objects always aggravated the pain There was no stiffness in the neck or restriction of movement in the upper limbs In the second group good the symptoms were mostly similar to those in the first group but the hand was often sensitive to cold and many patients had observed stiffness in the neck In the third group "fair stiffness in the neck and restriction of the movements of the cervical spine were marked The pain was particularly severe at night in all of these three groups and the patients often had to stand up and take pills These symptoms were probably due to cervical spondylosis and disc degeneration In the fourth group "poor although many of the symptoms and signs were similar to those in the other groups two important things were different—the position of the involved extremity did not affect the pain or other symptoms and the symptoms were not particularly disturbing at night

The duration of the symptoms had varied from three months to several years The length of the duration of the symptoms did not correspond to the result of the operation

Our results are very similar to those of *Ahonen* and *Karlen* Scalenotomy seems to be a beneficial minor surgical procedure in many cases of cervico brachial pain The pre operative diagnosis of sc

were immediately cured by the operation and that the result was permanent The second group of patients good stated that the operation relieved their symptoms markedly immediately and that their condition is much better now than before the operation The third group of patients "fair claimed that the operation was worth while and that they got some benefit from it The fourth group poor contains all the patients who stated that the operation was of no value to them No-one claimed that the operation had aggravated their symptoms or reported any other ill effects from the operation

TABLE 1

| Age | Female | Male | Total |
|---|---|---|---|
| 70–79 | – | 1 | 1 |
| 60–69 | 3 | 3 | 6 |
| 50–59 | 10 | 14 | 24 |
| 40–49 | 10 | 10 | 20 |
| 30–39 | 5 | 4 | 9 |
| 20–29 | 2 | 2 | 4 |
| | 30 | 34 | 64 |

TABLE 2

| Follow up period | Cases |
|---|---|
| Follow up period over 9 years | 7 cases |
| 7–9 years | 3 cases |
| 5–7 years | 9 cases |
| 3–5 years | 10 cases |
| 1–3 years | 20 cases |
| Under 1 year | 2 cases |
| | 51 cases |

The follow up study shows that 35 patients out of 51 that is about 69 per cent were cured or definitely improved by the small operation

What has the exact diagnosis been in these cases? One may say that in those cases where the condition did not improve the diagnosis had not been scalenus anticus syndrome In cases where the condition was practically cured immediately and permanently the scalenus anticus muscle certainly had something to do with symptoms Nearly all of the patients in the excellent group expressed spontaneously their sincere gratitude to the surgeon They pointed out that the conservative treatment had been of no value and that the operation produced immediate relief The results are described in Table 3

## SUMMARY AND CONCLUSIONS

The authors report the follow up examination of 64 cases of scalenotomy performed at the Orthopaedic clinic of the Helsinki University during the period 1951–63 The indication for operation had been failure of conservative treatment and strong suspicion that the scalenus anticus muscle was responsible for most of the neuro-vascular symptoms from the upper limb In most of the cases presented it was not possible to come to a definite diagnosis Follow up examination showed that in the 51 cases which were available for study 21 were cured and 14 obtained marked relief of their symptoms 5 further patients stated that the operation was worth while and only 11 of the 51 cases were failures In positive cases the relief was immediate and permanent This was regarded as mostly due to vascular symptoms The follow up period varied from a few months to over 12 years The pre operative duration of the symptoms was from three months to several years There were no cases of cervical rib The main symptom in successful cases had been complaints of persisting pain extending into the upper extremity The position of the involved extremity had usually an effect on the pain so that the patient could find a position where the pain was less and another where it became worse Carrying heavy objects particularly aggravated the symptoms The gripping and squeezing power of the affected hand was weakened The shoulder on the affected side was considered to be lower in most of the cases and there was definite tenderness to palpation over the region of the scalenus anticus muscle Occupation age sex and the amount of degenerative changes in the X rays of the cervical spine did not correspond with the result The authors consider that although the scalenus anticus muscle often played a secondary part in the pathology of production of the symptoms its cutting relieved the symptoms remarkably often If conservative therapy has failed and clinical and radiological examination exclude neoplasms and infections etc the operation of scalenotomy is worth remembering as a possible method of treatment A surprisingly large number of patients were very grateful for this operation as could clearly be seen from the remarks made in the follow up questionnaire Although we admit that the positive definite diagnosis of scalenus anticus syndrome is often impossible there can still be justification for scalenotomy In none of our cases did the condition become worse after the operation If the indications for scalenotomy are kept very strict many patients remain without relief

## RÉSUMÉ

Les auteurs rendent compte de l'observation de 64 cas de scalenotomie pratiquée à la Clinique Orthopédique de l'Université d'Helsinki pendant la période 1951–63. L'indication de l'opération avait été le résultat inopérant du traitement conservateur et le fort soupçon que le scalène antérieur était responsable de la plus grande partie des symptomes neuro-vasculaires constatés dans les extrémités supérieures. Dans la plupart des cas presentés il n'avait pas été possible de poser un diagnostic définitif. L'examen complémentaire révéla que sur les 51 cas qu'il a été possible d'étudier 21 étaient guéris et 14 avaient été essentiellement soulagés de leurs symptomes. 5 autres malades déclarèrent qu'il avait valu la peine de pratiquer l'opération. Dans 11 cas seulement sur ces 51 l'opération n'avait pas réussi. Dans les cas positifs le soulagement fut immédiat et permanent, principalement par rapport aux symptomes vasculaires. La période d'observation a varié entre quelques mois et plus de 12 ans. La durée des symptomes pré-opératoires avait varié entre trois mois et plusieurs années. Il n'y avait pas de cas de cote cervicale. Le principal symptome dans les cas qui ont été opérés avec succès était la plainte d'une douleur persistante s'étendant à l'extrémité supérieure. La position du membre avait généralement un effet sur la douleur. La malade pouvait ainsi trouver une position où la douleur était moindre et une autre où elle était pire. Le port d'objets lourds en particulier aggravait les symptomes. Le pouvoir d'étreinte et de pression de la main malade se trouvait affaibli. Du coté malade l'épaule était apparemment plus basse dans la plupart des cas et il y avait une sensibilité determinée à la palpation dans la région du muscle scalène antérieur. L'occupation, l'âge, le sexe et le nombre des modifications de dégénération de la colonne cervicale constatés aux rayons X ne correspondaient pas aux résultats. Les auteurs considèrent que bien que le scalène antérieur ne joue souvent qu'un role secondaire dans la pathologie qui produit les symptomes, sa section soulage des symptomes extrêmement fréquemment. Si la thérapie conservatrice n'a pas réussi et que l'examen clinique et radiologique exclut la présence de néoplasmes, d'infections, etc., il est bon de songer à la scalenotomie comme une méthode possible de traitement. Un nombre étonnamment élevé de malades a été très reconnaissant de cette opération, ce qui est clairement apparu des remarques portées sur le questionnaire rempli à l'occasion de l'examen complémentaire. Bien que nous admettions qu'il est souvent impossible de poser le diagnostic définitif

d un syndrome du scalene anterieur la scalenotomie peut neanmoins etre justifiee Dans aucun de nos cas l etat n a empire apres l operation Si les indications de la scalenotomie sont maintenues très strictes beaucoup de malades n obtiendront pas de soulagement a leurs douleurs

## ZUSAMMENFASSUNG UND SCHLUSSFOLGERUNGEN

Die Verfasser berichten über die Nachuntersuchung von 64 Fallen von Scalenotomie die an der orthopedischen Klinik der Universität von Helsinki wahrend der Zeit von 1951–63 ausgefuhrt wurden Die Operationsanzeige war das Versagen der konservativen Behandlung und der starke Verdacht dass der m scalenus anticus fur den grossten Teil der neuro vaskularen Symptome der oberen Gliedmasse verantwortlich war In den meisten der vorgestellten Falle war es nicht moglich zu einer bestimmten Diagnose zu gelangen Die Nachuntersuchung zeigte dass von den 51 Fallen die untersucht werden konnten 21 geheilt waren wahrend 15 eine bedeutende Erleichterung ihrer Symptome darboten 5 weitere Patienten erklärten dass die Operation der Muhe wert war und nur 11 der 51 Fälle schlugen fehl In positiven Fallen war die Erleichterung unmittelbar und dauernd Dies wurde angenommen war meist vaskularen Symptomen zuzuschreiben Die Zeit der Nachuntersuchung varierte von einigen Monaten bis zu 12 Jahren die präoperative Dauer der Symptome von 3 Monaten bis zu einigen Jahren Falle von Halsrippen wurden nicht gefunden Das Hauptsymptom in den erfolgreichen Fallen war Klagen über bestandige Schmerzen die in den Arm ausstrahlten Die Stellung der betroffenen Gliedmasse hatte in der Regel eine Wirkung auf die Schmerzen so dass der Patient eine Stellung finden konnte in der Schmerz geringer und eine andere in der er mehr ausgesprochen war Das Tragen von schweren Gegenstanden verstarkte die Symptome besonders Der Griff und die Druckkraft der befallenen Hand war geschwächt Die Schulter der ergriffenen Seite wurde in den meisten Fallen als tieferstehend angesehen und eine sichere Druckempfindlichkeit in der Gegend des m scalenus anticus war vorhanden Beschäftigung Alter Geschlecht und die Grosse der degenerativen Veranderungen der Halswirbelsaule im Rontgenbilde entsprachen nicht dem Ergebnis Die Verfasser sind der Ansicht dass obwohl der m scalenus anticus oft eine sekundare Rolle bei dem Entstehen der pathologischen Symptome spielte seine Durchschneidung doch in bemerkenswerter Weise oft zur Erleichterung der Symptome fuhrte Wenn die konservative Behandlung ergebnislos war

und die klinische und röntgenologische Untersuchung Neoplasmen und Infektionen etc. ausschliesst, dann ist der Gedanke an die Operation der Scalenotomie als eine mögliche Behandlungsmethode wertvoll. Eine erstaunlich grosse Anzahl von Patienten war sehr dankbar für diese Operation, wie aus den Bemerkungen auf den Fragebogen klar ersichtlich war. Obwohl wir zugeben, dass eine sichere, positive Diagnose des Scalenus anticus Syndromes oft unmöglich ist, kann die Scalenotomie doch berechtigt sein. In keinem unserer Fälle trat eine Verschlechterung des Zustandes nach der Operation auf. Wenn die Anzeigen für die Scalenotomie sehr streng gehalten werden, verbleiben viele Patienten ohne Erleichterung ihrer Beschwerden.

## REFERENCES


[illegible] The Scalenus Anticus Syndrome and the Results of its Operative Treatment. Am. [illegible] 1938.

[illegible]: Om [illegible]. Finska Läkaresällsk. Handl. 93: 121, 1953.

Brain, W. R.: Diseases of the Nervous System. Oxford University Press, London 19[illegible].

Campbell's Operative Orthopedics, Vol. [illegible] C. V. Mosby Co., Saint Louis 1953.

Finneson, B. E.: Diagnosis and Management of Pain Syndromes. W. B. Saunders, Philadelphia 19[illegible].

Gulling, M.: On the Scalenus Syndrome. Acta chir. Scandinav. [illegible] 19[illegible].

Hansen, [illegible] Neck and Shoulder Pain Syndromes. M. [illegible] Clin. N. Amer. [illegible] 1951, 19[illegible].

Kallio, K. E.: Personal communication.

Karlén, [illegible]: Scalenotomie. Acta chir. Scandinav. [illegible]: 63, 1945.

Kopell, H. P. & Thompson, W. A. L.: Peripheral Entrapment Neuropathies. Williams & Wilkins, Baltimore 1963.

Lange, M.: Orthopädisch-Chirurgische Operationslehre. J. F. Bergmann, München 1962.

McGregor, A. L.: A Synopsis of Surgical Anatomy. J. Wright, Bristol 1953.

Mercer, W.: Orthopaedic Surgery. E. Arnold, London 19[illegible].

Telford, E. D. & Mottershead, S.: Pressure at the Cervico-Brachial Junction. An Operative and Anatomical Study. J. Bone Jt. Surg. 30 B: [illegible] 1948.

Wiles, Ph.: Essentials of Orthopaedics. J. & A. Churchill, London 1955.

Acta orthop. Scandinav. XXXV, 67–73, 1964

From the Department of Surgery II, Sahlgrenska Sjukhuset,
University of Gothenburg, Sweden (Head: Professor Ragnar Romanus, M.D.)

# IS THE LENGTH OF HOSPITALIZATION FOR PATIENTS WITH FEMORAL SHAFT FRACTURES SHORTENED BY INTRAMEDULLARY NAILING?

*By*

HANS DENCKER

As a rule it is difficult to analyse the length of hospitalization for patients with femoral shaft fractures in regard to different methods of treatment owing to the influence of many factors not directly connected with the fracture treatment. Consequently, any comparison should be made with caution.

In *Lauritzen*'s series (1950) the mean period in hospital was 91 days for 30 patients with nailed fractures, and for 43 whose fractures had been treated with other methods it was 131 days.

At L. Böhler's Clinic *J. Böhler* (1951) reported a mean hospitalization of 45 days for closed nailing of 35 closed femoral fractures. Twenty-six patients with open fractures treated with intramedullary nailing were hospitalized for an average of 68 days.

In *Aronsson*'s insurance series (1956) the length of stay in hospital was 4¼ months on the average for closed methods, 4½ months for intramedullary nailing and 5¼ months for other methods of internal fixation.

*Palmer* (1957) gave 49 days as the mean period of hospitalization for 59 patients with nailed femoral fractures in whom the late course was not wholly dominated by multiple injuries or disease. If 2 cases of infection were excluded, the period was 45 days. The author expressed the view that this time in hospital should suffice after correct intramedullary nailing.

## MATERIAL

The present investigation is a study of the length of hospitalization of different methods of treatment for fractures of the femoral

TABLE 1

*Distribution of patients with [illegible] fractures according to length of hospitalization*

| Method of treatment | Hospitalization in months | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1-2 | 2-3 | 3-4 | 4 | 5-6 | 6 | [illegible] | 8-9 | 9-10 | 10-11 | 11 1 | 12 1 | 16 | |
| Closed method | | | | | | | | | | | | | | | |
| Traction | 1 | 9 | 32 | 15 | 34 | 16 | 13 | 7 | 8 | 4 | 2 | 4 | 3 | | [illegible]31 |
| Others | 3 | | | 1 | | 1 | | 1 | | | | | | | 6 |
| Open method | | | | | | | | | | | | | | | |
| Intramedullary nailing | 25 | 91 | 6 | 5 | [illegible]5 | 15 | | 6 | 6 | 3 | 1 | 4 | 11 | 8 | 33[illegible] |
| Encircling wire | 2 | 9 | 13 | 5 | 13 | 8 | | 5 | 3 | 3 | 1 | 2 | 4 | 4 | 9 |
| Plate and screw | [illegible] | | 10 | 10 | [illegible] | 2 | 2 | 3 | | 1 | | | 1 | | 36 |
| Others | 2 | 2 | 9 | 4 | 6 | 6 | 5 | 2 | 1 | | 3 | | 4 | | 41 |
| Transfixation | | | | 1 | | | | | | | | | 1 | - | 2 |
| Total | 35 | 111 | 160 | 1 6 | 83 | 45 | 24 | 24 | 15 | 11 | 7 | 10 | 21 | 12 | 06 |

TABLE 2

*Distribution of Patients with Open Fractures According to Length of Hospitalization*

| Method of Treatment | Hospitalization in months | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1-2 | 3 | 3-4 | > 4 | 5-6 | 6-7 | 7-8 | 8-9 | 9-10 | 10-11 | > 11-12 | > 12-18 | > 18 | |
| Closed methods | | | | | | | | | | | | | | | |
| Traction | | | 4 | 1 | 6 | 6 | 1 | 2 | 1 | – | 1 | 1 | 2 | 2 | 27 |
| Others | | | – | – | – | – | – | | – | 1 | – | – | – | – | 1 |
| Open methods | | | | | | | | | | | | | | | |
| Intramedullary nailing | 2 | 6 | 2 | 4 | 3 | 4 | 4 | 2 | – | 1 | 3 | 1 | 2 | 1 | 35 |
| Encircling wire | – | – | – | 1 | 1 | 1 | – | – | – | – | – | 1 | – | – | 4 |
| Plate and screws | | – | 2 | 1 | – | 1 | – | 1 | – | – | 1 | 1 | – | – | 7 |
| Others | | – | | – | 2 | – | | – | – | 1 | – | – | 2 | 4 | 9 |
| Transfixation | – | – | 1 | – | 1 | – | – | – | – | – | – | – | – | – | 2 |
| Total | 2 | 6 | 9 | 7 | 13 | 12 | 5 | 5 | 1 | 3 | 5 | 4 | 6 | 7 | 85 |

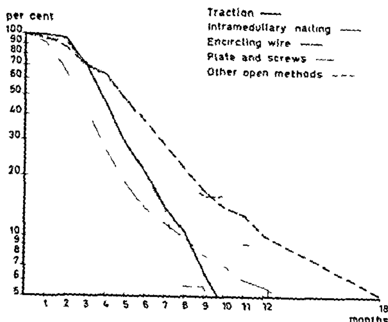



DIAGRAM 1
*Length of Hospitalization in Different Treatment Groups of Closed Fractures*

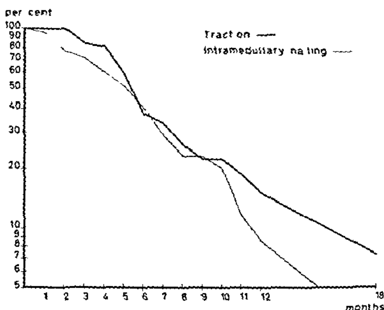



DIAGRAM 2
*Length of Hospitalization Following Traction and Intramedullary Nailing of Open Fractures*

applied at all except 4 Swedish hospitals during the three year period 1952 to 1954 The lowest age at the time of injury was 17 years Fractures caused by primary or metastasizing tumours are excluded Otherwise all cases are included After rejecting cases in which multiple injuries diseases or other factors affected the patient s stay in hospital there remain 706 closed and 85 open fractures in which the length of hospitalization was dependent only upon the fracture and its treatment

The duration of the stay in hospital in regard to different methods of treatment is given in Tables 1 and 2 as well as in Diagrams 1 and 2

It may be seen in Diagram 1 that half the patients with *closed fractures* treated with traction were hospitalized for less than 3¾ months and 10 per cent for over 8 months In the nailed closed fracture group this period was under 2½ months in 50 per cent of the cases and more than 8 months in 10 per cent As will be seen in Diagram 2 the time spent in hospital was of approximately equal length in *open fracture cases* treated with traction and in those fixed with an intramedullary nail

The hospitalization was more than 12 months in 7 cases of fracture treated with traction—in 5 due to delayed bone union in 1 to non union and in 1 to refracture

Twenty two patients with nailed fractures were kept in hospitals for over 12 months—in 10 due to infection in 6 to delayed bone union in 5 to non union and in 1 to refracture

In the encircling wire group the length of hospitalization exceeded 12 months in 8 cases—in 4 due to non union in 2 to delayed bone union and in 2 to infection

One patient whose fracture had been treated with a plate was kept in hospital for more than 12 months owing to non union

Ten patients with fractures treated with other open methods were hospitalized for over 12 months In 7 instances the reason was delayed bone union or non union and in 3 infection

## DISCUSSION

The length of time in hospital for intramedullary nailing has frequently been short (*Bohler* 1951 *Palmer* 1957) In the present series too this period was relatively short for most patients with nailed fractures—for half of them with closed fractures it was less than 2½ months The mean period of hospitalization is usually given As a result the range limits are often unclear In my investigation the number of patients who spent long periods at hospital after intramedullary nailing was considerable *Nineteen patients with nailed closed fractures* (6 per cent) stayed for over 12 months This was often necessitated by infection The fact that most of the patients were hospitalized for only

relatively short periods after nailing must be weighed against the extensive time required for a small proportion

Traction usually led to longer hospitalization than intramedullary nailing In half the patients with closed fractures the period exceeded 3¾ months On the other hand the really long stays in hospital were very few Only 3 (2 per cent) were kept for more than 12 months

## SUMMARY

This investigation is a study of the length of hospitalization of different methods of treatment for fractures of the femoral shaft applied at practically all Swedish hospitals during 1952 to 1954 The length of hospitalization was dependent upon the fracture and its treatment in 706 closed and 85 open fractures Most patients with a nailed closed femoral shaft fracture were hospitalized for a relatively short period half of them for less than 2½ months On the other hand 6 per cent were kept in hospital for more than 12 months In the closed fracture group treated with traction the length of hospitalization was longer than 3¾ months in 50 per cent of the cases but over 12 months in only 2 per cent Fixation with a plate led to approximately the same period of hospitalization as traction The longest time in hospital was recorded after fixation with encircling wire and other open methods Patients with open fractures treated with traction or with intramedullary nailing were kept in hospital for about the same length of time (in around 50 per cent of the cases for less than 5½ months)

## RESUME

Cette enquete porte sur l etude de la duree de l hospitalisation dans les differentes methodes de traitement des fractures du corps du femur appliquees dans les hopitaux suedois entre 1952 et 1954 La duree de l hospitalisation a dependu de la fracture et de son traitement dans 706 cas de fracture fermee et 85 cas de fracture ouverte La plupart des malades avec une fracture du corps femoral enclouee fermee ont ete hospitalises pour une periode relativement courte la moitie d entre eux pour moins de 2 mois et demi Toutefois 6 pour cent ont ete gardes a l hopital pour plus de 12 mois Dans les groupes des fractures fermees traitees par traction la duree de l hospitalisation depassait 3¾ mois dans 50 pour cent des cas et 12 mois dans seulement 2 pour cent des cas La fixation au moyen d une plaque a conduit approximativement

à la meme periode d hospitalisation que la traction La plus longue duree de l hospitalisation a ete enregistree apres fixation par encerclage et autres methodes ouvertes Les malades ayant des fractures ouvertes traites par traction ou par enclouage intramedullaire ont ete gardes à l hopital pendant approximativement la meme duree de temps (dans pour ainsi dire 50 pour cent des cas pendant moins de 5 mois et demi)

## ZUSAMMENFASSUNG

Diese Untersuchung hat zum Gegenstand die Länge des Kranken hausaufenthaltes nach verschiedenen Behandlungsmethoden für Ober schenkelschaftbruche die praktisch an allen schwedischen Kranken hausern von 19o2 bis 19o4 angewendet wurden Die Länge des Aufent haltes war von dem Bruche und seiner Behandlung bei 706 geschlossenen und 8o offenen Bruchen abhangig Die meisten Patienten mit einer genagelten geschlossenen Fraktur waren fur eine verhaltnismassig kurze Zeit am Krankenhause die Halfte von ihnen weniger als 2½ Monate Andererseits verblieben 6 Prozent mehr als 12 Monate am Kran kenhause In der Gruppe der geschlossenen Bruche die mittels Exten sion behandelt wurden dauerte der Krankenhausaufenthalt länger als 3¾ Monate in o0 Prozent der Falle doch uber 12 Monate nur in 2 Pro zent Fixierung mit einer Platte fuhrte zu ungefahr der gleichen Lange des Krankenhausaufenthaltes wie die Extension Die langste Zeit im Krankenhause wurde nach Drahtumschlingung und anderen offenen Methoden registriert Patienten mit offenen Bruchen die mittels Ex tension oder intramedullarer Nagelung behandelt waren wurden fur ungefahr die gleiche Zeitspanne am Krankenhaus behalten (ungefahr o0 Prozent der Falle fur weniger als o½ Monate)

## REFERENCES

*Aronsson H* Invaliditet efter femurdiafysfrakturer Nord Med 55 757 19 6

*B hl r J* Results in medullar nailing of ninety five fresh fractures of the femur J Bone Jt Surg 33 4 670 19 1

*Denck r H M* Fractures of the shaft of the femur A clinical stud based on 1 003 fractures treated in Swedish hospital during the three year period 19 to 19 4 Orstadius boktr ckeriaktiel lag G teborg 1963

*Laurit en C A* Me lf r m rg ikning någon forkortning av ardtiden på sjukhus? Sven ka LakT 47 1360 19o0

*Lalmer I* Marg pikning vid femurfrakturer Gran kning av ett material i I S der sjukhu ets kirurgiska klinik I Nor l Med 57 101 1957

Acta orthop Scandinav XXXI 74-89 1964

From the Surgical Department of the Maria City Hospital Helsinki Helsingfors
(Head Prof P I Tuovinen M Sc D)

# FEATURES OF AMPUTATION SURGERY AMONG CIVILIANS DURING THE PERIOD 1930-1960

By

RALF LINDHOLM

Better anesthesia control of shock management of sepsis and new methods in pre and postoperative care in combination with improved prosthetic devices and rehabilitation programs have brought about changes in amputation surgery since 1939

Medical and social development have had a great influence upon the morbidity mortality and age of the population Technology is responsible for a steadily increasing risk of injury from accident

These trends must be presumed to have affected the more or less accepted principles and main features of amputation surgery for disease and civilian injury One change in the professional attitude is in fact the generally adopted replacement of *zur Verth*s *(1923)* even lately approved sites-of election by the more limb saving levels of amputation of today

## PURPOSE OF INVESTIGATION AND METHODS OF STUDY

Mainly with a view to detecting changes in the composition of series amputation characteristics and philosophy the author has made a survey of the case records of nearly one thousand clinical amputations The operations were performed at a unit dealing with patients in need of emergency as well as planned surgery but without sections of rehabilitation and amputee service The area covered by this hospital is the capital city with somewhat under half a million inhabitants by the end of the period surveyed The number of annually registered patients has been near 5 000 except during the period of war between 1939 and 1945 which reflects the lower numbers of registered civilians

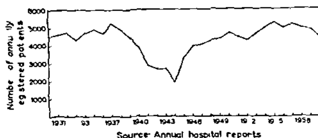



TABLE 1
*Annual Distribution of 133 466 Clinical Patients Admitted at the Maria City Hospital Surg Dept 1930–1960*

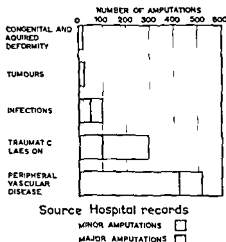



TABLE 2
*Amputations on 986 Limbs Performed at the Maria City Hospital Surg Dept 1930–1960 by Indications*

(Table 1) Approximately every second patient underwent some kind of surgery In this report interest is focused upon questions of operative indications age and sex frequency of amputation level of surgery primary operative risk and evaluation of trends revealed in the course of time

## REASONS FOR AMPUTATION

The indications subdivided into five main groups are presented in relation to numbers of amputations major and minor procedures being indicated (Table 2)

TABLE 3

*Sex Distribution of Patients Amputated for Civilian Reasons at the Maria City Hospital Surg Dept 1930–1960*

| Indication for amputation | Sex | | |
|---|---|---|---|
| | Male* | Female | |
| Peripheral vascular disease | 59.2 | 40.8 | 100.0 |
| Traumatic lesion | 86.5 | 13.5 | 100.0 |
| Infection | 69.1 | 30.9 | 100.0 |
| Growth | 40.6 | 59.4 | 100.0 |
| *Deformity* | 42.3 | 57.7 | 100.0 |
| Miscellaneous | 68.0 | 32.0 | 100.0 |
| Total | 66.2 | 33.8 | 100.0 |

Source Hospital records

TABLE 4

*Per Cent Relations between Main Groups of Indication for Amputation by Different Sex Maria City Hospital Surg Dept 1930 1960*

| Sex | Peripheral vascular | Traumatic lesion | Infection | Growth | Deformity | Misc ll | Total |
|---|---|---|---|---|---|---|---|
| Male amputees | 49.3 | 33.6 | 9.1 | 2.8 | 2.1 | 3.1 | 100.0 |
| Female amputees | 66.0 | 10.2 | 7.9 | 7.1 | 5.6 | 3.3 | 100.0 |

Source Hospital records

*Peripheral vascular disease* This commonest cause of amputation has been shown to comprise non diabetic gangrene (368) diabetic gangrene (89) embolism (35) and occasional cases of venous thrombosis aortic aneurysm and complication from varicose veins

*Traumatic lesions* Fracture laceration and traumatic (accidental) amputation have occurred in equal numbers amounting to 8 9ths of all injuries Thermal chemical radiation and electric injury account for the remaining 1/9th

*Infections* This third group in order of frequency consists of cases of non specific osteitis (49) bone and joint tuberculosis (21) and luetic osteitis (2) with infection of soft tissue and septicaemia accounting for the remaining 1 4th of all bacterial conditions

*Tumours* Malignant growths arising from connective tissue cartilage and bone are together equal in number to those of epithelial origin Only once has amputation been performed for a benign lesion

*Congenital and acquired deformity* These have all been of a minor

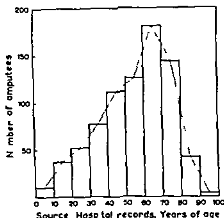



TABLE 5
*Age of Amputees at the Time of Surgery Maria City Hospital Surg Dept 1930–1960*

type including cases of Dupuytren s contracture hammer toes an chylosis and contraction of finger joints onychogryphosis etc

Apart from these common reasons for amputation single cases of pathologic fracture neurotrophic lesion and decubital ulcer and ele phantiasis have been met

Re amputation in the course of the same hospital stay was performed for advancing gangrene with or without signs of infection on sixty limbs (38 non diabetic and 22 diabetic) In four instances re-operation was performed in cases where the primary reason for amputation had been infection Ten re amputations in traumatic cases were registered Bilateral amputations amount in number to sixteen for vascular dis order eleven for frostbites nine for other traumas and five for minor toe deformities

### SEX AND AGE CHARACTERISTICS OF AMPUTEES

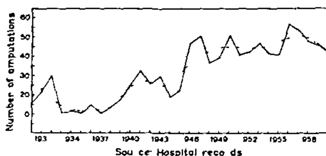
2 3rds of all amputees were men This male preponderance depends on the fact that many more men than women have undergone amputa tion for vascular disease and traumatic injury (Table 3) The internal relation of operative indications however is the same in both sex groups thus the most frequent reason for amputation among the women was peripheral vascular disorder which was relatively even commoner than amongst the men (Table 4) This circumstance can be explained by the very sparse occurrence of traumatic incidents leading to amputation among the females

TABLE 6

*Per Cent of Different Main Reasons for Amputation at the Maria City Hospital Surg Dept 1930—60 in Ten Yearly Interval Groups of Patients Chronological Age*

| Years of age | Peripheral vascular | Traumatic lesion | Infection | Growth | Deformity | Misc | Total |
|---|---|---|---|---|---|---|---|
| 0-10 | – | 100.0 | – | – | – | – | 100.0 |
| 10-20 | 2.7 | 75.7 | 8.2 | 10.8 | 2.7 | – | 100.0 |
| 20-30 | 1.9 | 82.7 | 7.7 | 5.8 | 1.9 | – | 100.0 |
| 30-40 | 26.0 | 59.7 | 11.7 | – | 2.6 | – | 100.0 |
| 40-50 | 28.8 | 42.3 | 11.7 | 1.8 | 7.3 | 8.1 | 100.0 |
| 50-60 | 56.4 | 16.7 | 11.0 | 8.0 | 5.5 | 2.4 | 100.0 |
| 60-70 | 71.3 | 8.3 | 8.8 | 5.0 | 2.8 | 3.8 | 100.0 |
| 70-80 | 88.2 | 1.4 | 4.9 | 3.5 | 2.0 | – | 100.0 |
| 80-90 | 97.6 | 2.4 | – | – | – | – | 100.0 |
| 90-100 | 100.0 | – | – | – | – | – | 100.0 |
| Total | 55.0 | 25.5 | 8.7 | 4.2 | 3.4 | 3.2 | 100.0 |

Source Hospital records




Source Hospital records

TABLE 7

*Annual Distribution of 980 Clinical Amputations on Civilian Indications Performed at the Maria City Hospital Surg Dept 1930 1960*

More than fifty per cent of the amputees were aged between 60 and 80 years at the time of surgery (Table 5) A study of ten year groups from 0 to 100 reveals a continually diminishing proportion of trauma and simultaneously a steadily increasing proportion of amputations for vascular trouble (Table 6)

Up to the age of 50 trauma has been found to dominate and thereafter the group of vascular disorders has provided the most frequent reason for amputation Thus the youngest group includes almost only traumas and the oldest group gangrenes from obliterative arterial disease only The most tragic cases seem to be the double above knee child amputee victims of railroad accidents

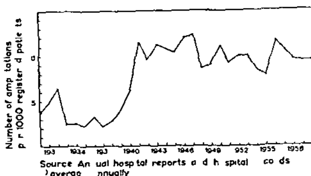



TABLE 8
*Amputations on Civilian Indications Performed at the Maria City Hospital Surg Dept 1930–1960*

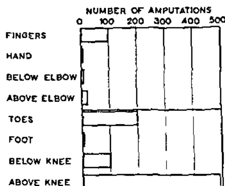



TABLE 9
*Amputations on 986 Limbs at the Maria City Hospital Surg Dept 1930–1960 by Level of Surgery*
*Source Hospital records*

## FREQUENCY OF AMPUTATION

Calculations indicate a frequency of between 3 and 12 amputations per thousand surgical patients admitted (Tables 7 and 8) The former number relates to the period 1930–1940 and the latter to the time after 1945 Thus there is a rather steep rise of the frequency curve through the period 1940–1945 Taking into consideration that approximately fifty per cent of all registered surgical patients have been operated upon the rate of amputations in relation to all surgery done makes 6 to 20 per thousand the latter number being indicative of the figures of later years

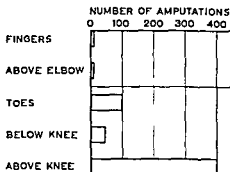



TABLE 10

*Amputations on 531 Limbs for Peripheral Vascular Disease Performed at the Maria City Hospital Surg Dept 1930–1960 by Level of Surgery*
*Source Hospital records*

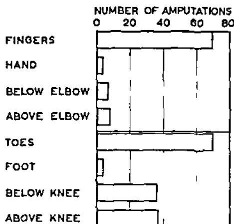



TABLE 11

*Amputations on 282 Limbs for Traumatic Lesions Performed at the Maria City Hospital Surg Dept 1930–1960 by Level of Surgery*
*Source Hospital records*

It has not been possible to obtain a reliable figure for the frequency in relation to the population of the area served on the basis of this series if all reasons for surgery are taken into account However regarding vascular disorders the figures have in fact been giving significant and valuable ratings The large majority of patients *suffering* from arterial disease have been admitted to the hospital in question The annual frequency of amputation for peripheral vascular disease may thus be estimated at about one amputation per ten thousand in

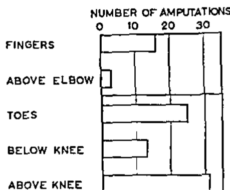



TABLE 12

*Amputations on 9[illegible] Limbs for Infections Performed at the Maria City Hospital Surg Dept 1930–1960 by Level of Surgery*
*Source Hospital records*

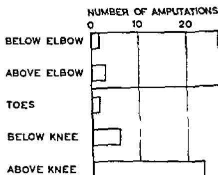



TABLE 13

*Amputations on 3[illegible] Limbs for Tumours Performed at the Maria City Hospital Surg Dept 1930–1960 by Level of Surgery*
*Source Hospital records*

habitants according to the recent average amputation rate This implies a rate of one hundred persons yearly in a town with a population of a million

## LEVEL OF SURGERY

Only 12 per cent of the limbs subjected to amputation have been upper extremities while the majority or 78 per cent have been lower extremities (Table 9) Of all amputations 2/3rds have been performed

at a level requiring a prosthesis at the thigh leg ankle and foot or upper arm lower arm or wrist

When level is considered in relation to the various reasons for surgery it can be shown that the lower thigh has been the site of election in vascular disease (Table 10) while thigh and lower leg have been subjected to amputation an equal number of times in cases of trauma (Table 11) Infectious disease has usually been treated by rather near by amputation (Table 12) while malignant growth has prompted operation at a high level upper arm or thigh (Table 13) The deformities of this series have been uniformly treated by minor peripheral amputation

TABLE 14

*Death Rates in Different Main Groups of Indication for Amputation Surgery Performed at the Maria City Hospital 1930–1960*

| Indication for amputation | Dead |
|---|---|
| Peripheral vascular disease | 26 6 |
| Traumatic reason | 5 5 |
| Infection | 11 8 |
| Growth | 12 9 |
| Deformity | 0 0 |
| Total (major amputations) | 2[illegible] 6 |
| Total (all) | 15 1 |

Per cent total number amputated patients in each group of indication
Source Hospital records

OPERATIVE RISK

The results have been calculated in terms of risk of death in the post operative period of hospital stay The figures appear to indicate the importance of underlying disease as a cause of failure rather than operative trauma and stress (Table 14)

The greatest risk has been encountered in vascular disease The deaths from amputation for infections were mostly due to sepsis which is nowadays of little more than historic importance (Table 15)

Of the deaths 24 (21 per cent) occurred during the first day post operatively 19 after amputation for vascular disease and 5 for traumatic lesions Of all 138 deaths 71 (51 per cent) took place in the period before the eighth day postoperatively 43 (31 per cent) in from the eighth to the thirtieth day 17 (12 per cent) in from the thirtyfirst to the sixtieth day and 7 (5 per cent) after the sixtieth day

TABLE 15

*Number of Deaths among Patients Amputated for Civilian Reasons at the Maria City Hospital Surg Dept 1930–1960 by Indications for Surgery*

| Main groups of indication | Preoperative diagnosis | Number of deads | |
|---|---|---|---|
| Peripheral vascular disease | obliterative arterial disease | 79 | |
| | diabetic arterial disease | 23 | |
| | embolic arterial disease | 10 | 82 6 % |
| | aortic aneurysm | 1 | |
| | caval thrombosis | 1 | |
| Traumatic lesion | laceration | 4 | |
| | fracture | 2 | |
| | traumatic amputation | 4 | |
| | burns | 1 | 7 9 % |
| Infections | sepsis | 6 | |
| | osteitis | 1 | 5 8 % |
| | tuberculous disease | 1 | |
| Growth | malignant growth | 4 | 2 9 % |
| Miscellaneous | pseudarthrosis | 1 | 0 8 % |
| | Total | 138 | 100 0 % |

During primary stay in surg dept after operation
Source Hospital records

Primary mortality during hospital stay after above knee amputation rated 25 per cent Of all deaths the majority (125 138) followed above knee amputation The below knee amputation rate was found to be 2 per cent only The surprisingly high operative risk in above elbow amputation (7/19) was caused by heart disease (with embolism) (3) progressing sepsis (2) multiple complicated trauma (1) and crush injury (1) Four patients *succumbed after minor amputations three after* removal of one or more gangrenous toes for vascular reasons and one after amputation of a finger for infection of soft tissue with signs of septicaemia all these because of progressing generalized disease and none immediately after surgery

## TRENDS APPARENT FROM A STUDY OF CHRONOLOGIC SEQUENCE

Comparison of the period 1930–1944 and 1945–1960 has revealed a significant rise in the mean age of persons undergoing amputation for

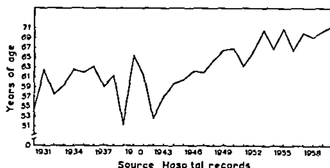



TABLE 16
*Mean Age of Patients Amputated for Peripheral Vascular Disease Maria City Hospital Surg Dept 1930–1960*

TABLE 17
*Mean Age of Patients Amputated for Civilian Reasons at the Maria City Hospital Surg Dept 1930–1960 by two Time Intervals of Observation*

| Period years | Mean age in years ) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Peripheral vasc lis | Traumatic lesion | Infection | Growth | Deformity | Misc | Total |
| 1930–44 | 59.0 | 35.7 | 45.1 | 54.0 | 46.8 | 36.3 | 50.3 |
| 1945–60 | 67.3 | 36.0 | 54.7 | 53.2 | 51.7 | 48.6 | 56.5 |
| Total | 65.0 | 35.9 | 50.9 | 53.3 | 50.2 | 46.6 | 54.8 |

At the moment of surgery
Source Hospital records

vascular disease (Table 16) and infection while no rise in the mean age of amputees operated for trauma can be shown (Table 17)

Moreover an actual as well as a relative increase in the number of operations for vascular disorders and traumatic lesions can be detected coincidentally with the rise in the mean age (Table 18) The slight decrease in the frequency of amputations for traumatic reasons since 1957 is evidently explained by the establishment of other units taking over a part of the accident service in the region covered

Concerning the level of surgery peripheral amputations of a minor type were performed in 12 per cent of all operations for vascular disease before 1945 and in 19 per cent after that date Correspondingly of the former limbs about 23 per cent were re operated at a major site and of the latter 26 per cent This seems to indicate a moderately increased inclination to peripheral surgery of later years the gain however being

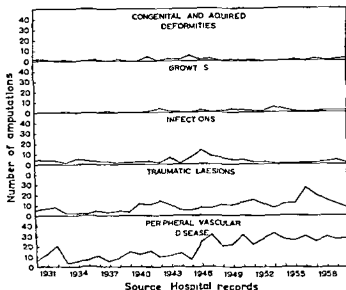



TABLE 18
*Amputations Performed at the Maria City Hospital Surg Dept 1930–1960 by Indications*

compensated by a moderate increase in the rate of failure from progressing lesion involving re amputation The incidence rate (30 per cent) of re amputation after below knee amputation is based on too small a figure to allow comparison in time

## CONCLUSIONS AND DISCUSSION

In the near future we are rather likely to experience a growing number of elderly amputees sufferers from vascular disorders alongside with more people undergoing amputation for traumatic injury This will place a heavy load upon our institutions providing rehabilitation service

Effective organization of prophylaxis and rehabilitation requires knowledge of the causation frequency and results of amputation surgery This series supports the opinion that the medical and social progress during the last two decades has not been of any prophylactic value Regarding rehabilitation we know that success in fitting young and middle aged people with limbs is the rule in contrast to the case of *geriatric amputee who presents a more difficult problem* Opinions differ widely concerning this problem Reports indicate that not more

than fifty per cent of the people amputated after 65 years of age will use their prosthesis. A very pessimistic view is presented by *Kelley & Janes* from the Mayo clinic, who found that only 29 per cent below knee and 14 per cent above knee geriatric amputees were successfully limb fitted and able to walk. It should not be forgotten that prescription of an artificial limb is one task and to gain satisfactorily from limb fitting another. *Avoiding waste requires the co-ordination of surgery, training* and prosthetic research and the acceptance of certain principles. Such questions, however, go beyond the purpose of this investigation. It may be mentioned that there are fresh opinions which favour the prescription of at least a provisional prosthesis for every amputee over 65 years of age if not bedridden. It has not been possible to have the end results of this series yet, apart from primary mortality. It thus contributes knowledge to the point where the special prosthetic training in the old meaning begins.

Regarding the frequency of amputation published reports are scarce. Reliable figures come from limb fitting units (Roehamptom, Great Britain and Orthopaedic Hospital Copenhagen). These indicate a somewhat higher incidence of amputation for traumatic reasons than does this series. This feature is well explained by the high incidence of failure of recovery and the uselessness of limb fitting many sufferers from arterial disease represented in abundance in this series. The high rate of major re-amputation after minor peripheral amputation illustrates clearly the systemic character and unfavourable prognosis in vascular disorders.

The essential tasks thus seem to be situated in the fields of traumatic and geriatric medicine. All successful efforts to rehabilitate young amputees will no doubt be well rewarded. The importance of the training of the geriatric amputee is a humanitarian rather than a strictly economically justified social necessity. The trends speak in favour of decentralizing measures in the organization of amputee training for the quiescent old people, whereas the young and still adjustable amputee needs specialized training and education which can only be offered by a few centralized units.

There is no need even to stress that reparative and reconstructive vascular surgery may come to play the most important role in the sphere of prophylaxis and treatment of disorders causing amputation.

## SUMMARY

Nearly one thousand clinical amputations performed at a surgical unit not equipped with a special amputee service are surveyed

The reasons for amputation and their frequency were 1) Peripheral vascular disease (54 per cent) traumatic lesion (29 per cent) infections (9 per cent) tumours (3 per cent) congenital and acquired deformity (2 per cent) and miscellaneous (3 per cent)

The male preponderance in 2 3rds of all amputations was found to depend on a higher incidence of vascular disease and trauma as a cause of amputation In the ten year age groups most amputations were performed between 60 and 70 years More than fifty per cent were 50–79 years old at the time of surgery Trauma dominates up to the age of 50 and thereafter vascular disorder prevails as a reason for amputation

The rate of amputations in relation to all kind of operations has been estimated to be 6–20 per thousand the higher figure being indicative of later years while annual frequency of amputation for peripheral vascular disease is about one per ten thousand inhabitants

The different levels of amputation in relation to the various indications are depicted 12 per cent of the limbs were upper extremities and 78 per cent lower extremities 2 3rds of the total were amputated at a major site

The primary mortality rate of above knee amputation equalled 25 per cent and below knee amputation 2 per cent only Most deaths (51 per cent) took place during the first week postoperatively somewhat fewer (31 per cent) in the following second third and fourth weeks The risk of death in the postoperative period of the hospital stay seemed apparently to depend more on the underlying disease than the surgical trauma

## RESUME

Il a ete procédé a l etude de près d un millier d amputations cliniques effectuees dans un département chirurgical non équipe d un service spécial d amputation

Les raisons de l amputation et leur frequence étaint 1) maladie vasculaire périphérique (54 pour cent) lesion traumatique (29 pour cent) infections (9 pour cent) tumeurs (3 pour cent) déformite congénitale et acquise (2 pour cent) et divers (3 pour cent)

Il ressort de cette analyse que la preponderance masculine de 2 3 de toutes les amputations etait due a une frequence plus elevee des maladies vasculaires et traumatiques comme causes de l amputation Si

than fifty per cent of the people amputated after 65 years of age will use their prosthesis A very pessimistic view is presented by *Kelley & Janes* from the Mayo clinic who found that only 29 per cent below knee and 14 per cent above knee geriatric amputees were successfully limb fitted and able to walk It should not be forgotten that prescription of an artifical limb is one task and to gain satisfactorily from limb fitting another Avoiding waste requires the co ordination of surgery training and prosthetic research and the acceptance of certain principles Such questions however go beyond the purpose of this investigation It may be mentioned that there are fresh opinions which favour the prescription of at least a provisional prosthesis for every amputee over 65 years of age if not bedridden It has not been possible to have the end results of this series yet apart from primary mortality It thus contributes knowledge to the point where the special prosthetic training in the old meaning begins

Regarding the frequency of amputation published reports are scarce Reliable figures come from limb fitting units (Roehamptom Great Britain and Orthopaedic Hospital Copenhagen) These indicate a somewhat higher incidence of amputation for traumatic reasons than does this series This feature is well explained by the high incidence of failure of recovery and the uselessness of limb fitting many sufferers from arterial disease represented in abundance in this series The high rate of major re-amputation after minor peripheral amputation illustrates clearly the systemic character and unfavourable prognosis in vascular disorders

The essential tasks thus seem to be situated in the fields of traumatic and geriatric medicine All successful efforts to rehabilitate young amputees will no doubt be well rewarded The importance of the training of the geriatric amputee is a humanitarian rather than a strictly economically justified social necessity The trends speak in favour of decentralizing measures in the organization of amputee training for the quiescent old people whereas the young and still adjustable amputee needs specialized training and education which can only be offered by a few centralized units

There is no need even to stress that reparative and reconstructive vascular surgery may come to play the most important role in the sphere of prophylaxis and treatment of disorders causing amputation

Operationen wurde auf 6–20 per tausend geschätzt. Die höhere Zahl weist auf die späteren Jahre und die jährliche Häufigkeit der Amputation wegen peripherer Gefässerkrankungen von ungefähr einer auf zehntausend Einwohnern hin.

Die verschiedenen Amputationshöhen in Bezug auf die verschiedenen Anzeigen werden dargestellt. 12 Prozent der Gliedmassen betrafen die oberen und 78 Prozent die unteren Extremiteten und 2.3 davon wurden an den Hauptstammen amputiert.

Die primäre Sterblichkeit der Oberschenkelamputationen war 25 Prozent und der Unterschenkelamputationen nur 2 Prozent. Die meisten Todesfälle (51 Prozent) traten in der ersten post operativen Woche auf. Etwas seltener (31 Prozent) ereigneten sie sich in der folgenden zweiten, dritten und vierten Woche. Die Gefahr des Todes in der post operativen Periode des Krankenhausaufenthaltes schien augenscheinlich mehr von der zu grundeliegenden Erkrankung als vom chirurgischen Trauma abzuhangen.

## REFERENCES

*Gillis L.* Amputations.—William Heinemann Medical Books Ltd. London 1954.

*Jansen K.* Amputation Frequency and Cause.—Prosthetics international Committee on prostheses braces and technical aids International Society for the Welfare of Cripples Copenhagen 1960.

*Kelley & Janes* Quoted by Marquardt W. in Handbuch der Orthopadie Band IV/Teil 2.—Georg Thieme Verlag Stuttgart 1961.

*Klopsteg P. & Wilson P.* Human Limbs and their Substitutes. McGraw Hill Book Company Inc. New York Toronto–London 1954.

*Marquardt W.* Gliedmassenamputationen und Gliedersatz.—Wissenschaftliche Verlagsgesellschaft MBH Stuttgart 19 5.

Acta orthop Scandinav XXXV 91–97 1964

From Martina Hansens Hospital Sandvika Norge (Head John K Hald M D)

# THE VALUE OF HISTOLOGICAL AND BACTERIOLOGICAL EXAMINATION IN TUBERCULOSIS OF BONES AND JOINTS

*By*

JOHN HALD JR

## INTRODUCTION

The frequency of the tuberculosis of bones and joints shows constant decrease This is true generally but varies greatly from country to country

In Korea tuberculous spondylitis still often occurs (*Paus* 1960) and in Brazil the situation pertaining to this sector is as it was in the USA at the turn of the century (*Campos* 1954)

Moreover publications from the USA and Scandinavia (*Alvik* 1949 *Fellander* 1954 *Hald* 1954 *Smith* 1955) show that tuberculous diseases of bones and joints still exist although the conditions are under control

The diagnosis of these illnesses are based on the patient s history the clinical findings and the X ray examination However to make the diagnosis with safety one must show the presence of the bacilles by cultivation or inoculation or by a histological examination which alone shows tuberculosis

*Chormly* (1926) stated that the microscopic tissue examination was the most satisfactory *Swift* (1936) found that the preoperative diagnosis of the lesions of bones and joints was correct in about 75 per cent of the cases Frozen section diagnosis corresponded to ordinary histological examination more than 80 per cent of the time and to guinea pig inoculation 84 per cent of the time Among 100 patients who probably had the spondylitis *Fellander* found the in 92 cases Histological examination was carried out on 86 patients with positive findings in 81 cases in the case of the other 5 the bacilles were found with guinea pig inoculation In all 84.5 per cent of the inoculations were found to be positive and 77 per cent of the cultivations In our day

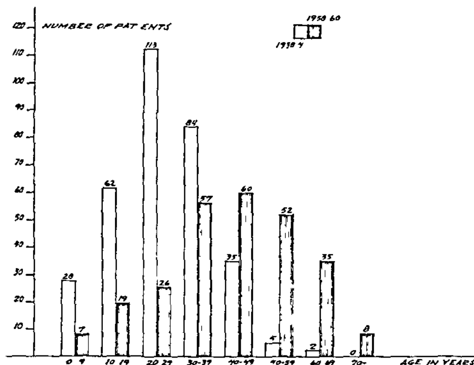



*Fig 1*
Distribution of age

with several effective antituberculous drugs in use the diagnosis must be completely correct in order that one may be able to evaluate the results of the treatment From this follows the importance of producing material for bacteriological and histological examination The resistance some cherished earlier now seems to have terminated (*Holmdahl* 1960)

## MATERIAL

To evaluate the accuracy of the histological and bacteriological examination of the bone and joint diseases before and after the introduction of the treatment with tuberculostatics we have gone through the patient material of Martina Hansens Hospital for 2 periods of 3 years each 1938–40 and 1958–60 The material comprises respectively 327 and 264 patients

The table and figure reflect the decrease of the lesions of bones and joints For both periods there was found a preponderance among men a condition which was known previously The distribution of age in

dicates a tendency that is typical for all tuberculous illnesses. The average age for the 1st period is 26.5 years and for the 2nd period 43 years. Roughly speaking it would appear as if we had treated in both periods patients who were born about 1910–15.

## SEX AND AGE

TABLE 1
*Sex Distribution*

| | Women | Men | Total |
|---|---|---|---|
| 1938–40 | 153 | 174 | 327 |
| 1958–60 | 114 | 150 | 264 |

## HISTOLOGY AND BACTERIOLOGY

TABLE 2
*Localization of Lesion with the Diagnosis Confirmed by Histological or Bacteriological Examination. In Brackets Number Examined with Negative or without Samples*

| | 1938–40 | 1958–60 |
|---|---|---|
| Spine | 41 (99) | 55 (39) |
| Sacro iliac | 16 (10) | 6 (1) |
| Trochanter symphysis ischium | 10 (2) | 21 (2) |
| Hip | 33 (31) | 48 (18) |
| Knee | 12 (1) | 25 (2) |
| Leg ankle foot | 18 (13) | 13 (2) |
| Upper extremity | 22 (11) | 23 (2) |
| Chest wall | 8 (0) | 6 (1) |
| Total | 160 (167) | 197 (67) |

Table 2 shows to what extent we have verified the diagnosis bacteriologically and/or histologically. Seen as a whole the diagnosis was confirmed in the 1st period in 48.9 per cent of the cases and in the 2nd period in 74.6 per cent. The survey of the localization of the tbc lesions states principally from where the material for bacteriological and histological examination was taken. In cases with several localizations the samples were taken from the most dominant lesion. Every patient is registrated only once. Spondylitis is the most usual manifestation

In the years 1938–40 the bacteriological examinations were performed by Prof. *Anton Brandt*, Norges Veterinærhogskole, in the years 1958–60 by Statens Institutt for Folkehelsen. Almost all of the histological examinations were made by Prof. dr. med. *Leiv Kreyberg*, Rikshospitalets laboratorium for patologi (Pathological Laboratory).

with about 40 per cent of all cases in both periods The relative frequency of the coxitis seems to be increasing the other manifestations have occurred about the same extent as before

TABLE 3

*Comparison of the Results of Bacteriological and Histological Examination Bact Positive Means Positive Findings of the Bacilles on Bacteriological Examination etc*

| | 1938–40 | 1958–60 |
|---|---|---|
| Bact positive and hist positive | 62 | 108 |
| Bact pos hist negative | 5 | 8 |
| Bact pos | 70 | 21 |
| Hist pos | 19 | 15 |
| Hist pos bact neg | 4 | 45 |

The results of closer analysis of how the positive diagnoses were made are shown in Table 3 It appears in addition that in the 1st period the the bacillus was cultivated 137 times i e in 85 6 per cent of the positive diagnoses Histological diagnosis was made 85 times i e in 53 1 per cent of the cases In the 2nd period the was cultivated from 137 patients i e in 70 per cent of the positive diagnoses and positive histological examinations were made among 168 patients i e in 85 2 per cent of the cases

TABLE 4

*Comparison of the Results of Positive Bacteriological and Histological Examinations at the Different Localizations of the Disease*

| | 1938–40 | | | 1958–60 | | |
|---|---|---|---|---|---|---|
| | Bact + | Bact + Hist + | Hist + | Bact + | Bact + Hist + | Hist + |
| Spine | 36 | 3 | 2 | 6 | 35 | 14 |
| Sacro iliac | 5 | 10 | 1 | 0 | 5 | 1 |
| Trochanter etc | 2 | 5 | 3 | 3 | 10 | 8 |
| Hip | 13 | 14 | 6 | 6 | 22 | 20 |
| Knee | 4 | 6 | 2 | 8 | 10 | 7 |
| Ankle etc | 5 | 7 | 6 | 1 | 9 | 3 |
| Upper extremity | 7 | 13 | 2 | 6 | 12 | 5 |
| Chest wall | 3 | 4 | 1 | 1 | 3 | 2 |
| Total | 75 | 62 | 23 | 31 | 106 | 60 |

In Table 4 there is set up a survey of how the bacteriological/histological diagnosis is represented for the different groups of the localization of the disease In all it seems that the histological examinations yield more than they did previously and of particular significance is the

fact that the histological diagnosis of the the *spondylitis now seems* to be so solidly established Most of the coxitis and metastases to the pelvis can be histologically confirmed while for upper extremities and knees we ought to have results both of bacteriological and histological examinations before the diagnosis can be made or eventually excluded

The evolution shows that with increasing frequency we were able to produce samples for bacteriological histological examinations because now with tuberculostatics at hand we can operate so much more safely than before There are only 3 negative samples in the material of the 1st period but in the 2nd period there are in all 24 negative samples all for histological examinations For the 1st period there are 163 samples from 327 patients *i e* 49 9 per cent and for the 2nd period 221 samples from 264 patients or 83 7 per cent

In the last period we found that patients with positive findings of the bacilles had received treatment with PAS INH in about 6 3 weeks while patients with positive histological examinations had received treatment in about 7 6 weeks before the sample was taken for examination The duration of the same premedication for the 24 patients with *negative samples according to histological examination shows an average* of about 15 6 weeks

## CONCLUSIONS

1 The average age of patients with tuberculous diseases of bones and joints has increased by about 16 5 years in the course of the 20 year period 1938–1958

2 The diagnosis is confirmed with histological and or bacteriological examinations for about one half of the cases in the 1st 3 year period and about three fourths in the 2nd

3 For the 1st period most of the *positive findings were based on* bacteriological examination for the 2nd on histological examination

4 The number of samples for bacteriological and histological examination are both relatively and distinctly greater in the 2nd period the *histological examination* showing the most marked increase This is probably due to greater operating frequency under proctection of tuberculostatics

5 Bacteriological and histological examinations are both still absolutely necessary for the diagnosis of tuberculous diseases of bones and joints

## SUMMARY

1938–40 327 patients with tuberculous diseases of bones and joints were treated in Martina Hansens Hospital Sandvika 1958–60 264 patients The average age increased by 16 5 years in the course of the 20 year period The diagnosis was confirmed for 48 9 per cent of the cases in the 1st period 85 6 on bacteriological and 53 1 per cent on histological examination for 74 6 per cent of the cases in the 2nd period 70 0 per cent on bacteriological and 85 2 per cent on histological examination

## RESUME

Entre 1938 et 1940 327 patients souffrant de maladies tuberculeuses des os et des articulations ont ete en traitement à l Hopital Martina Hansen de Sandvika et entre 1958 et 1960 264 patients L age moyen s est accru de 16 5 ans durant cette periode de 20 ans Le diagnostic a éte confirme dans 48 9 pour cent des cas pendant la premiere periode 85 6 pour cent sur la base d un examen bacteriologique et 53 1 pour cent sur celle d un examen histologique et dans 75 6 pour cent des cas pendant la deuxième periode 70 0 sur la base d un examen bactériologique et 85 2 pour cent sur celle d un examen histologique

## ZUSAMMENFASSUNG

1938–40 wurden 327 Patienten mit Knochen und Gelenkstuberkulose am Martina Hansen Krankenhaus Sandvika behandelt und 1958–60 waren es 264 Patienten Das Durchschnittsalter nahm im Verlaufe des 20 jährigen Zeitraumes um 16 5 Jahre zu Die Diagnose wurde in 48 9 Prozent der Falle wahrend der ersten Periode bestatigt 85 6 Prozent davon mittels bakteriologischer und 53 1 Prozent mittels histologischer Untersuchungen in 74 6 Prozent der Fälle wahrend der zweiten Periode davon 70 0 Prozent mittels bacteriologischer und 85 2 Prozent mittels histologischer Untersuchungen

## REFERENCES

1 *Alvik I* Tuberculosis of the spine Acta chir Scandinav Suppl 141 199 pp disp 1949

2 *Campos Oswaldo P* Bone and joint tuberculosis and its treatment J Bone Jt Surg 37–A 937–966 1955

3 *Fellander M* Radical operations in tuberculosis of the spine Acta orth p Scandinav Suppl 19 117 pp disp 1954

4 *Ghormley R K* Joint disease A clinical pathological study J Bone Jt Surg *8* 858–883 1926

5 *Hald J* Treatment of bone and joint tuberculosis with streptomycin and PAS Acta tuberc Scandinav XXX 89–104 1954

6 *Holmdahl H C son* Tuberculosis of the knee Acta orthop Scandinav *20* 19 49 1950

7 *Paus B* Behandling av tuberkuløs spondylitt i Korea T Den norske Lægeforen *3* 132–134 1960

8 *Smith A Def* The treatment of bone and joint tuberculosis J Bone Jt Surg 37 A 1214–1229 1955

9 *Swift W E* Frozen section diagnosis of tuberculous joints J Bone Jt Surg *18* 641 647 1936

Acta orthop Scandinav XXXV 98-116 1964

From the Department of Orthopaedic Surgery The Permanente Medical Group and the Kaiser Foundation Hospital San Francisco California

# PROCESSED HETEROGENOUS BONE IMPLANTS (BOPLANT, SQUIBB) AS GRAFTS IN SPINAL SURGERY[1,2]

*By*

PAUL H HARMON

With the advent of fully compatible non immunogenic prepared heterogenous bone (*Boplant Squibb*[3]) several different applications have been made in osseous (orthopaedic) surgery The use of this type bone in human surgery was undertaken only after basic (chemical and immunologic) studies had been completed and it had been demonstrated that this type bone derivative was easily vascularized and was biologically compatible These studies were carried out both in an ectopic site (2) (anterior chamber of the rat eye) and in an orthoptic area (3 4) (long bones of animals) In the bone grafting experiments comparisons were made between autogenous bone and the prepared heterogenous bone for capacity to become vascularized and to unite in long bone defects Such comparisons of the behaviour of Boplant in the host osseous area of another species in the crucial test for a prospective bone grafting material The orthoptic experiments demonstrated (1) The initial incorporation of both types of bone was similar and (2) After six months the heterografts were more thoroughly remodelled than the autografts as judged by gross radiographic histologic and microradiographic criteria The large marrow vascular spaces of the prepared bone derived from young calves were more favorable to

[1] Aided by Research Grants from the Kaiser Foundation and from the Squibb Institute for Medical Research

[2] Read at the Ninth Congress of the Pan Pacific Surgical Association Honolulu Hawaii November 6 1963

[3] Generous quantities of the prepared protein and fat extracted lyophilized Boplant were furnished by *James A Dingwall* M D of the Squibb Institute for Medical Research

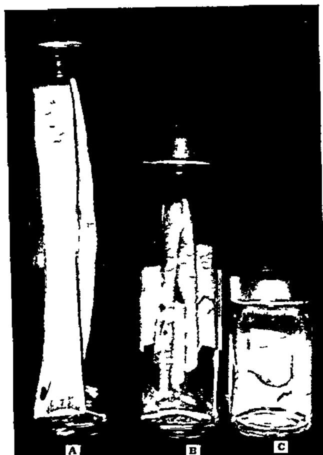



*Fig 1a*

Appearance of Boplant cortical and cancellous grafts in the sterile lyophilized state Saline is added to the sterile bottles six to twelve hours prior to proposed use (A) Cortical strip (B) Cancellous strips and (C) Cortico-cancellous plugs

osseous substitution than even some types of autogenous bone With these clear cut experimental findings it seemed appropriate to challenge the clinical dictum that there is nothing like the patients own bone

Detailed and comparative studies of this type heterologous bone in human spinal surgery were then undertaken by this author The recipient sites for bone grafts in this type surgery are particularly advantageous because of (1) marked osseous vascularity (2) excellent wide surface contact and (3) a deep somatic site well surrounded by

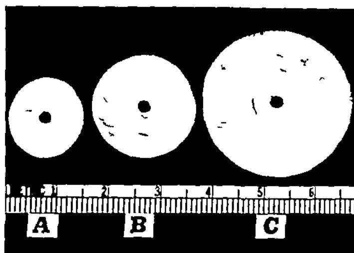



*Fig 1 b*

Three sizes of cortico cancellous plugs (A) One half inch diameter (B) Three fourths inch diameter and (C) One and one eighth inch diameter

vascular soft tissues Operative technique will not be discussed in this paper except as brief descriptive references to orient the reader to the different type applications when the anatomy and roentgen findings are being discussed Those interested in the detailed operative technique are referred to appropriate publications (6 8 10) Fig 1 illustrates the types and shapes of bone (Boplant) utilized in these studies

It should be noted here that spinal stabilization by bone grafting operations upon the vertebral bodies themselves is a phase of surgery that has been perfected and practiced upon a wide scale only in recent years (Cervical spine *Cloward* (5) and *Robinson et al* (12) Lower lumbar spine *Harmon* (6–11)) This type surgery has been applied to the unrelieved acute chronic and recurrent intervertebral disc syndromes of both areas and their complications chronic vertebral arthrosis and the spinal instability of chronic long standing intervertebral disc degeneration Adequate and usually full relief of symptoms can even be expected in about ninety per cent of patients who have not been able to secure relief from non operative treatments or from other types of operations They are the procedures of choice for certain painful spinal conditions following trauma and for salvage in failures from previous excisional disc operations and/or spinal fusions Documentation of these statements is available in the articles of the bibliography

There are many positive advantages to an anterior vertebral fusion

(1) non weakening of the posterior spinal structures (2) avoidance of contact with neural elements and (3) the important practical fact that this is a systematic and extensible surgical procedure the practical results of which equal or exceed those of any other type operation in either the cervical or the lumbar area This is equally true in primary operations best demonstrated in the first operation of an uncomplicated single level case[1] of persistingly symptomatic lumbar discopathy There is immediate relief of both lumbago and radicular symptoms in most cases without complicating paresthesias from nerve root stimulation The morbidity hospitalization period and over all disability is about the same from the primary anterior excision fusion procedure as from a posterior excisional operation Patients who have had both procedures without exception state that the anterior operation is easier *providing a second field is not opened for the removal of an autogenous bone graft*

The need for a substitute for autogenous bone grafts does not have to be argued Use of bone from another source is impressive to patients and surgeons alike who both remember cases with excellent pain free function at the definitive operative site with pain and disability at the graft donor site When another bone grafting operation sometimes needs to be performed many patients can no longer spare bone from the usual donor sites or are unwilling to do so

The first operation performed by the author with a Boplant heterograft was an anterior lumbar interbody fusion (May 1 1958) Although the method of preparation of this particular heterograph was somewhat inferior to that now in use the take was prompt and satisfactory The resultant spinal stabilization relieved the patient of his complaints In the interim and up to six months prior to the preparation of this report the following numbers and types of surgical operations have been performed

(1) Anterior interbody lumbar fusions utilizing only cortical grafts of Boplant for the intervertebral defect created by osteotome excision of the intervertebral disc and portions of the cortical osseous vertebral plates (*16 cases*)

---

[1] An "uncomplicated single level case of lumbar disc pathy" refers to a primary operation on a patient with a corresponding extent of lumbar disc pathology

Excepting that the back of the worker in heavy industry must be protected from stress until fusion is rather far advanced (four to six months)

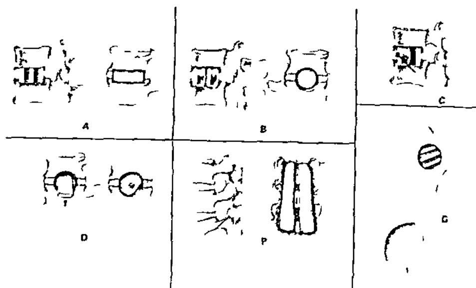



Fig ?

Some technical variations of applying intervertebral bone grafts and various applications of Boplant in spinal osseous surgery (A) Intervertebral "sandwich" grafting with alternate layers of cortical and cancellous bone following disc removal and excision of portions of the cortical osseous plates (B) "Coin" grafting with circles of full thickness iliac grafts (C) Combining "sandwich" and "coin" grafting with semifixation of the ventral graft with a metallic screw The latter is indicated when the ventral graft cannot be countersunk or when it is slightly loose (D) Inter vertebral grafting with multidirectional pieces of cortical bone (P) Use of strips of cancellous Boplant as onlays to augment the osseous fusion mass in posterior lumbar fusions (G) Cancellous strips used to fill the circular iliac defect created by removal of fullthickness grafts

(2) Anterior lumbar fusions performed by "sandwich grafting" with alternate layers of cortical and cancellous Boplant (*103 cases*)
(3) Anterior lumbar interbody fusions posterior portion of the grafting performed with cortical and/or cancellous grafts of Bo plant with the anterior portion of the interbody grafts made with a full thickness autogenous iliac "coin" graft (*18 cases*)
(4) Same type operation as (3) supplemented with grafts of can cellous Boplant in the lateral "wings" of the interbody grafted area (*31 cases*) (see also Fig 2)
(5) "Plug" grafting with Boplant in anterior cervical interbody fu sions (Cloward operative technique (5)) (*40 cases*)
(6) Cancellous Boplant replacement into iliac defects of patients created by the removal of full thickness grafts (*12 cases*)

(7) Utilization of cancellous slabs of Boplant to supplement autogenous iliac chips in posterior fusions in the lower lumbar area (*15 cases*)

Some comparisons will be made to similar operations where only autogenous bone was used. The simultaneous use of two types of grafts heterogenous and autogenous *in some cases had the double purpose of* testing the reactions of host graft recipient site to the presence of both types of grafts and the clinical effect of only removing a modest amount of bone from the ilium for one of the grafts. Thereby the discomfiture of the patient at the donor site was minimized. The further question of the presence of a small or modest amount of autogenous iliac bone having a favorable influence on transformation and consolidation of the whole grafted bed is important.

The largest number of operations has been the anterior lower lumbar fusions (categories 1 to 4 inclusive). The second most frequently performed operation was the anterior cervical interbody fusion (category 5). The post operative observation of patients who have had the first type operation has been five years or more in category 1 and six months to three years in categories 3 and 4. The cervical interbody plug fusions have been observed from six months to three years (75 per cent more than eight months). By eight months the final end result of cervical interbody fusions is well patterned. By twelve months a reliable similar opinion is available about the lumbar interbody fusions. Some additional roentgen changes occur in the grafted area in the cervical spine for the next four months and in the lumbar area for the next eighteen months or even longer in some few cases (see Figs 3–6).

### *Methods of Study and Evaluation of Results*

Detailed and objective conclusions as to the practicability of using Boplant for spinal fusions is obtained from the following types of inquiry. (1) A comparative study of the post-operative course and the end results from autogenous *grafting as compared with cases in which Boplant has been used by observation on* (a) instability symptoms (pain and lumbar muscle spasm), (b) serial roentgen changes that might bring out desirable or undesirable features of either type graft, (c) pseudarthrosis (fusion failures), and (d) time required to obtain a clinically adequate fusion so the patient can safely discard external spinal support. (2) Statements from the patients (sometimes of ques



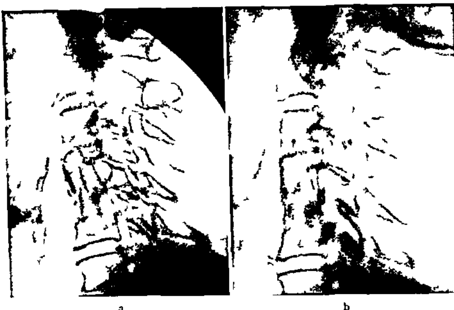
a b

*Fig 3*

(a) Three level (C-3 C-4 C-5 C-6) anterior cervical fusion seven months post operative utilizing Boplant plug grafts Union is present but the grafts have not as yet reached uniform density compared with the recipient bed (b) Two level (C-4 C-5 C-6) anterior cervical fusion twenty two months post operative Autogenous full thickness iliac graft at C-4 5 and Boplant cortico cancellous plug at C-5 6 Full maturation and consolidation of grafts and recipient bed

tionable objective value) about the relief from preoperative symptoms In speedy relief from symptoms the obvious advantage conferred on patients in not opening a site for the donation of an autogenous graft must of course be kept in mind

Objective opinions as to the speed and completeness of incorporation of bone grafts have to be made in large measure from roentgenograms This is a somewhat unsatisfactory tool due to the lag often as long as several weeks in the accumulation of sufficient calcifying density to effect roentgenographic shadows as compared to the actual biological process as revealed by microscopy or by microradiography But, allowances can be made for this In rendering an opinion about the presence and quality of osseous union there are some fundamental differences in the roentgenograms (and also in the biology) of the assimilation of



a b

*Fig 5*

Illustrating stages of incorporation of Boplant grafts in a two level cervical (C-4 C 5 C 6) fusion (a) three months post operative demonstrating preservation of the cortical graft shadows and (b) twenty months full incorporation of grafts and solid fusion

autogenous cortical bone to that of Boplant cortical pieces There are also some relatively minor but distinctive differences in incorporation of cancellous plugs of the two types Requirements for structural support in the cervical interbody fusions dependent upon changes in the cancellous plugs thin cortex on one side are slight as compared to the important weightbearing capabilities of cortical bone in the lumbar spine Therefore the necessity of using some cortical bone in the lower lumbar spinal fusions

There are some serious technical difficulties in the roentgenography of the lumbar and the lumbosacral areas due to thickness of the part and to overlying shadows of neighbouring bone especially the ilium and sacrum To minimize these technical difficulties the roentgenologist[1] who has made the films for these graft transformation studies has employed short focal spot magnification technique

In the interpretation of roentgen films it is helpful to distinguish

[1] *Martin S Abel M D*



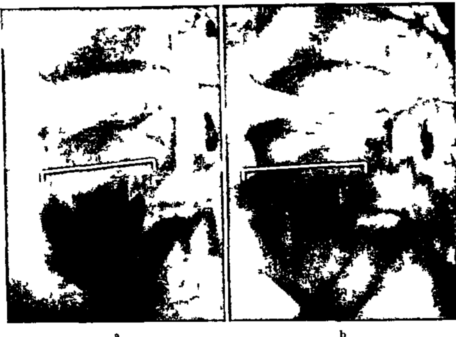
a b

*Fig 3*

(a) Three level (C-3 C-4 C-5 C-6) anterior cervical fusion seven months post operative utilizing Boplant plug grafts Union is present but the grafts have not as yet reached uniform density compared with the recipient bed (b) Two level (C-4 C-5 C-6) anterior cervical fusion twenty two months post operative Autogenous full thickness iliac graft at C 4 5 and Boplant cortico cancellous plug at C-5 6 Full maturation and consolidation of grafts and recipient bed

tionable objective value) about the relief from preoperative symptoms In speedy relief from symptoms the obvious advantage conferred on patients in not opening a site for the donation of an autogenous graft must of course be kept in mind

Objective opinions as to the speed and completeness of incorporation of bone grafts have to be made in large measure from roentgenograms This is a somewhat unsatisfactory tool due to the lag often as long as several weeks in the accumulation of sufficient calcifying density to effect roentgenographic shadows as compared to the actual biological process as revealed by microscopy or by microradiography But allowances can be made for this In rendering an opinion about the presence and quality of osseous union there are some fundamental differences in the roentgenograms (and also in the biology) of the assimilation of



a b

*Fig 6*

Lateral roentgenograms of stages of cortical Boplant assimilation after (a) six months and (b) nine months in a 4? year old male patient grafted at lumbar five The two posterior grafts in (a) demonstrate the perigraft "halo" described as Stage II (Page 106) A slightly more advanced stage of graft union assimilation of Stage III the "halo" having now disappeared except from the most posterior graft The bracket indicates the depth of the intervertebral graft recipient bed

and discrete in roentgenograms as progressively heavier shadows

IV *Final maturation* is a complete blending of graft and recipient bed Cortical grafts irrespective of their origin never completely lose their identity Traces of this type bone often a considerable portion of such cortical grafts persist indefinitely as dense shadows in roentgenograms Such "ghosts" of cortical bone have unnecessarily worried some observers but there is no evidence symptomatic or otherwise that such bone is undesirable This dense bone is not a dead sequestrum but is a failure of remodelling of all the dense and thick trabeculae of the cortical grafts

The details of this process of maturation can be evaluated exactly only from microscopic preparations Roentgenograms of the intact pa

tient contain too many irrelevant shadows Later reference will be made to correlation of symptoms with the above stages of graft alterations (see Page 110)

TABLE 1

*Boplant Intervertebral Grafts Compared to Two Types of Autogenous Bone (Lower Two Lumbar Levels)*

| | Boplant-sandwich grafts | | Autogenous iliac coin grafts | | Autogenous tibial sandwich grafts | |
|---|---|---|---|---|---|---|
| | L-5 | L-4 | L-5 | L-4 | L-5 | L-4 |
| Number of Cases | 31 | 15 | 51 | 15 | 54 | 10 |
| Percentage Incidence of Postoperative Lumbago | 5[illegible] | 53 | 37 | 20 | 19 | 50 |
| Return to work (Median) Months | 3 | 2 5 | 3 | 3 | 2 5 | 2 5 |
| Time (months) for Stage III Graft Assimilation | 4 5 | 4 | – | – | 8 | 6 |

Impossible to estimate substitution incorporation of cancellous grafts

† Additional cases to bring the number to that stated in category 2 (103 cases) are persons grafted at both L-5 and L-4 These are *not* (for the purposes of comparison) *simple cases* and are not considered in this comparative tabulation

## RESULTS FROM THE OPERATIONS

### (A) Anterior Lumbar Interbody Fusions

Some comparative clinical data is summarized in Table 1 Illustrations of some of the methods of intervertebral bone grafting are shown in Fig 2 As a control background to the results of Table 1 a considerable number of lumbar interbody fusions with (a) autogenous tibial sandwich grafts 221 cases and (b) autogenous iliac full thickness coin grafts 105 cases (total 326 cases) have been performed The results with the autogenous grafts are uniformly longer term results than those from Boplant and are two to three year or longer results The *five to six year results 221 cases autogenous tibial sandwich grafts'* are 62 per cent *excellent*[1] and 29 per cent *good*[1] *two to three*

1 Excellent results are patients whose symptoms are fully relieved and who are physically active without restriction and without any painful recurrences Good" results are a highly acceptable outcome with patients physically active but who may have some very minor non disabling pains at irregular intervals *e g* with weather change An average follow up of 97 per cent of the operations was obtained Relief refers to freedom from *both* low back pain and radicular pains



a b

*Fig*

Lateral r entgenograms of imilar stages of cortical Boplant graft assimilation after (a) three months and (b) after six months in a 29 year old female patient grafted at lumbar five The graft "halo" (Stage II) is wide and well-demonstrated in (a) In the additi nal three months this has disappeared and (b) shows well advanced Stage III (interlocking of graft and recipient bed trabeculations) union Younger p r ns with acti e o seous metabolism transform and assimilate grafts in this area with greater speed

*year results 10) cases autogenous full thickness iliac coin grafts* were 73 per cent *excellent* and 16 per cent *good average highly accepl al le results* both type autogenous grafts 90 per cent

Comparisons of the above results from autogenous anterior inter vertebral grafting in the lumbar area with the cases of Table 1 shows a favorable graft assimilation union time in the cases in which the pre pared heterogenous bone (Boplant) was used The clinical results were equally good with both types of grafts There was a greater incidence of post operative lumbago in the first month with cortical pieces of the prepared bone More important for comparative purposes is data com

paring stages of graft assimilation as revealed in roentgenograms with the clinical data available in 99 cases (or 73[1] per cent of cases of categories 1 to 3 inclusive) The roentgen data was derived from exposures made by short focal spot technique with magnification at three six and nine months post operatively and in some cases one and two years following operation Estimations of the stage of union were made on the basis of the four stages previously described Reaching Stage IV from Stage III is a step as prolonged in time as the total of the first three stages Nevertheless most post operative and nocturnal lumbago ceases in the latter part of Stage II and sufficiently advanced clinical union exists at this time to allow normal activities short of stress exercising and heavy work or sport Only minimal or intermittent support of the back required Some careful patients need no bracing

Although there was a greater incidence of low back pain (nocturnal *and otherwise) associated with sandwich grafting with Boplant the* dates of return to work and grade of assimilation of grafts through Stage III were favourable to Boplant A further analysis of cases (*e g* Fig 7) in which screw fixation of grafts to one vertebral body was performed showed that post operative and nocturnal low back pain could be largely abolished by this means Final amalgamation assimilation of grafts was accelerated with Boplant as compared with autogenous tibial grafts possibly because of wider osteoid seams and marrow spaces of cortical Boplant Aside from these few differences there was no radical difference in behaviour of the groups as a whole with the different type grafts studied The cases of category 4 (cancellous Boplant in the wings lateral to a large transvertebral drill hole filled with cortical Boplant) demonstrated further accelerated time of union and corresponding less post operative lumbago (see also results of Table 2)

While the groups of Table 2 are not strictly comparable (except for *the sandwich grafting technique see Fig 2)* either as to numbers or technique it is observed even with the small numbers of cases involved that there was no radical difference between any of the groups (see also Table 1) This demonstrates comparability in the post operative status and results with grafts of the two origins There were spectacular cases with short hospital stay and complete and permanent relief of symptoms in both groups The factors of near ideal fitting of graft to vertebrae the absence of severe arthrosis (11) and a one level operation

[1] The smaller number of cases available for this comparison is due to the elimination of cases that did not fit into a uniform technique relative to graft position thickness and estimated surface contact of grafts

were the important factors in both groups that conditioned a favourable course and results Further detailed study of the steps of the heterogenous graft transformation correlated with age groups (decades) revealed no differences until the patients were 60 years of age or beyond

TABLE 2
*Results from Lower Lumbar Spondylolisthesis*

| | Boplant (Squibb) | | | Autogenous graft (controls) | |
|---|---|---|---|---|---|
| | Sandwich graft (category 2) | Cortical [illegible] on auto-co[illegible]n graft ([illegible] 3) | Cortical and [illegible] Boplant [illegible] (category 4) | Sandwich graft (controls) | Autogenous full thickness bone grafts (controls) |
| Number of Cases | 103 | 18 | 31 | 2[illegible]1 | 105 |
| Results (Percentage) | | | | | |
| Excellent | 59 | 67 | [illegible]7 | 62 | [illegible]3 |
| Good | 34 | 32 | 19 | 29 | 20 |
| Fair | 5 | 1 | 3 | 4 | 5 |
| Poor | 2 | 0 | 0 | 5 | 2 |

*Descriptive terms are previously defined (Footnote Page 108) Relief refers to freedom from both low back pain and radicular pains*

† For length of follow up observation see Pages 108–109 Most of the control patients prior operations with autogenous grafts were observed one to two years longer than those grafted with Boplant

In no case was there suggestion of any inflammatory response to the use of the heterogenous grafts as the post-operative temperature curves and local reactions were the same and leukocyte counts and red cell sedimentation rates were normal in both groups There were no instances of pyogenic infection in any of the cases considered in this report and no neurological complications

## RESULTS FROM THE OPERATIONS

### (B) *Anterior Cervical Interbody Fusions*

Cortical cancellous Boplant plugs (see Fig 1) were used in the basic Cloward intervertebral drilling technique in cervical interbody fusions on 40 patients There was no technical difficulty in placing the plugs and the follow up rate was 100 per cent These operations were performed at one level in five cases at two levels in 27 cases and at three levels in eight cases The post operative observation period has

been one to two and a half years (80 per cent more than a year and a half) The results were excellent 32 cases (80 per cent) good six cases (15 per cent) and fair two (5 per cent) These operations were all performed for cervical arthrosis (Three illustrative cases are shown in Figs 3 and 4 )

As compared with full thickness autogenous iliac plugs the cancellous portion of the Boplant plugs is somewhat friable Therefore grafts at two or more levels need support by a rigid brace extended to the upper half of the thorax front and back for approximately 12 weeks and in some instances up to 16 weeks Neglect of this complete precaution in one case resulted in minimum cervical kyphus of 10 degrees but this was asymptomatic The result in some control cases (70 patients autogenous iliac grafts) was 95 per cent excellent and good

## RESULTS FROM THE OPERATIONS

*(C) Iliac Defects Produced by Trephine Graft Excisions Filled with Boplant and the Adjuvant Use of Cancellous Boplant Slices in Posterior Chip Type Spinal Fusions*

The first mentioned application (iliac defects) was in 12 cases No incompatibilities were observed and roentgen follow up in all instances for more than one year periods failed to show any evidence of sequestration of the bone No surface inflammatory reactions were observed The second application (onlay in posterior spinal fusions) was in 15 cases The slices of cancellous Boplant (thickness 3 to 4 mm ) were onlayed to a bleeding bed of minced autogenous bone

## CONCLUSIONS

1 The prepared heterogenous lyophilized bone (Boplant Squibb) has been applied in several forms as grafts for anterior spondylodesis for posterior spinal fusions and for other auxiliary applications *e g* to fill *iliac defects from removal of full thickness circular grafts The results* in all have equaled those obtained with autogenous grafts

2 Several technical variations of applying Boplant and autogenous grafts alone or in combinations are described (a) Plug grafting for cervical spondylodesis by the Cloward technique has been without technical failures (no pseudarthrosis) in the hands of the author (b) Spondylodesis in the lower lumbar area requires maximum sized grafts with adequate cortical bone to withstand the stresses of this area

3 Relief of most or all symptoms in difficult and intractible cases of chronic and/or recurrent discogenic syndromes complicated by arthrosis in these two areas in patients in whom non operative treatments have failed has been obtained in 90 per cent in the lower lumbar spine and in 95 per cent in the cervical spine

4 Moderate friability and the larger marrow spaces of the cancellous portions of the prepared bone require external supportive precautions (bracing) in the post-operative period Two or three cortical surfaces are required for intervertebral support in the lumbar region

5 There is some clinical and radiological evidence that the grafts of the prepared bone (Boplant Squibb) are incorporated with the host recipient bed with speed and completeness equal to and in some cases exceeding that of autogenous bone

6 Detailed radiological studies (short focal spot magnification technique) of the stages of graft conversion incorporation are described These indicate full and adequate osseous union sufficient to *discard bracing in the cervical region by two or three months* and to permit *reasonable physical activity without bracing* for patients whose lumbar spine has been grafted by three to four months

7 Fusion failures (pseudarthrosis) from anterior spondylodesis in the lumbar area have been less with the prepared bone (one per cent) than with autogenous bone (five per cent)

8 Boplant is a satisfactory type of bone satisfying all requirements for bone grafting in the human spine under spine under the conditions of use described in this report The omission of a graft donor site is gratifying to both patients and surgeon

## ADDENDUM

During the 18 months elapsing between evaluation of the cases of this report and the present time the author has used cortico-cancellous plugs of Boplant for anterior cervical fusions in 20 additional cases Various cortical and cortico-cancellous combinations of Boplant with or without a single circle graft of full thickness iliac autogenous bone have been used as grafts in 172 additional anterior lumbar fusions Tight fitting grafts with peripheral obliquely inserted plugs of cortical Boplant have achieved better immediate graft immobilization and an almost ideal convalescence free of low back pains The clinical course of these cases has been even more favourable than those reported in the article

### SUMMARY

Boplant (PHB Squibb) a completely compatible protein and fat extracted lyophilized bone (cortical and/or cancellous) has been used in human surgery for anterior interbody fusions lumbar 137 cases cervical 40 cases replace iliac defects made by removal of full thickness grafts, 12 cases to supplement posterior lower lumbar chip fusions 15 cases The follow up has been over two years and some cases have been followed twice this period all to a stable end result The post operative course rate and result of union was compared to 221 cases of autogenous tibial sandwich grafts to 105 cases of autogenous iliac coin grafts both lumbar and anterior interbody fusions and to 70 cases of anterior cervical fusion with autogenous iliac coin grafts Rate of union and the negligible incidence of non union in the lumbar area slightly favoured the prepared heterologous bone (PHB) and were no different in the cervical area There was no evidence of biologic incompatibility and no infections or inflammatory reactions The results indicated that Boplant was quite satisfactory for the type operations on the human spine as described The roentgen stages of osseous reunion are described

### RESUME

Boplant (PHB Squibb) un extrait de proteine et de graisse d os lyophile (cortical et/ou spongieux) completement compatible a ete utilise en chirurgie humaine pour fusion anterieure des vertebres lombaires 137 cas cervicales 40 cas remplacement de defectuosites iliaques par l enlevement de greffes de pleine epaisseur 12 cas comme supplement pour la fusion posterieure d eclats de vertebres sacrees 15 cas La periode d observation a ete de plus de deux ans et quelques cas ont ete observes deux fois cette periode afin d etablir un resultat final Le cours post operatoire et le resultat de la soudure ont ete compares a 221 cas de greffes « sandwich » d os tibial autogène a 105 cas de greffes cuneiformes iliaques autogenes de fusions anterieures des vertebres lombaires et a 70 cas de fusion anterieure des vertebres cervicales avec greffes cuneiformes iliaques autogenes Le pourcentage de la soudure et l incidence negligeable de la non soudure dans la region lombaire est legerement plus favorable avec l os hétérologue prepare (PHB) et ne presentait aucune difference dans la region cervicale Il n y avait pas semble t il d imcompabilite biologique pas d infection ou de reactions inflammatoires Les resultats indiquent que Boplant a ete

entierement satisfaisant pour les operations de la colonne vertebrale du type decrit les etapes radiologiques de la soudure osseuse son decrits

## ZUSAMMENFASSUNG

Boplant (PHB Squibb) ein vollstandig verträgliches Protein und fettextrahierter lyophilierter Knochen (Rinden und oder Markknochen) wurden unter chirurgischen Eingriffen am Menschen zur vorderen Fusion von Wirbelkorpern verwendet Lendenwirbel – 137 Falle Halswirbel – 40 Falle Auffullung von iliakalen Defekten die nach Entfernung von die ganze Knochendicke umfassenden Transplantaten entstanden waren – 12 Falle zur Ergänzung einer ruckwartigen Spähnchenfusion der unteren Lendenwirbelsaule – 15 Fälle Die Beobachtungszeit ist uber zwei Jahre gewesen und einige Falle sind doppelt so lange alle bis zu einem stabilen Endergebnis beobachtet worden Der postoperative Verlauf die Häufigkeit und das Ergebnis der Vereinigung wurde mit 221 Fallen von autogenen Sandwich Spahnen mit 105 Fallen von autogenen iliakalen coin (Munzen) Spahnen für beide Lendenwirbel – und vordere Zwischenwirbelvereinigung und mit 70 Fallen von vorderer cervikaler Fusion mit autogenen iliakalen coin" Spähnen verglichen Die Haufigkeit der Vereinigung und das seltene Vorkommen von Nichtvereinigung in der Lendengegend sprach etwas zu Gunsten des praparierten heterologen Knochens (PHB) und zeigte keinen Unterschied in der Cervikalregion Keinerlei Zeichen von biologischer Unverträglichkeit und keine Infektionen oder entzuliche Reaktionen wurden beobachtet Die Ergebnisse zeigten an dass Boplant fur die beschriebenen Operationsarten an der menschlichen Wirbelsaule vollständig zufriedenstellend war Die Rontgenstadien der knochernen Vereinigung werden beschrieben

## REFERENCES


1 *Abel M S Harmon P H & Dingwall J A* Processed Heterogenous Bone for Anterior Interbody Spinal Fusions in the Cervical and Lumbar Regions a Brochure Accompanying a Scientific Exhibit at the 30th Annual Meeting of the American Academy of Orthopaedic Surgeons 1963

2 *Anderson K J Dingwall J A Schmidt J Lecocq L & Clawson D K* Effect of Particle Size of Heterogenous Bone Transplant and Host Tissue Histological Stud J Bone Jt Surg 43-A 996–1004 1961

3 *Anderson K J Karges D E Dingwall J A & Jousey J* Experimental Evaluation of Processed Heterologous Bone Transplants Clinical Orthop 29 30 240 1963

4 *Bassett C A L & Creighton D K Jr* A Comparison of Host Response to Cortical Autografts and Processed Calf Autografts J Bone Jt Surg 44-A 842 854 1962

5 *Cloward R B* Lesions of the Intervertebral Disks and Their Treatment by Interbody Fusion Methods Clinical Orthop 27 51-77 1963

6 *Harmon P H* Anterior Extraperitoneal Lumbar Disk Excision and Vertebral Body Fusion 1 A Study of Long Term Results 2 Operative Technique Including Observations upon Variations in the Left Common Iliac Veins and their Connections Clinical Orthop 16 169-198 1961

7 *Harmon P H* The Saline Injection Test for Lumbar Disc Degeneration Ann Surg 156 767-775 1962

8 *Harmon P H* Anterior Excision and Vertebral Body Fusion Operation for the Intervertebral Disc Syndromes of the Lower Lumbar Spine Two to Four Year Results in 244 Cases Clinical Orthop 26 107-127 1963

9 *Harmon P H & Abel M S* *Correlation of Multiple Objective Diagnostic* Methods in Lower Lumbar Disc Disease Clinical Orthop 28 132-151 1963

10 *Harmon P H* Surgical Technique for Anterior Interbody Fusion Special Reference to Avoiding Complications Clinical Orthop In press

11 *Harmon P H* Indications for Spinal Fusion in Lumbar Discopathy Instability and Arthrosis 1 Anatomic and Functional Pathology and Review of Literature 2 Results from Various Types of Operations on the Lumbar Spine in the Presence of Spinal Arthrosis Clinical Orthop 34 73-107 1964

12 *Robinson R A Walker A E Ferlic D C & Wiecking D K* The Results of Anterior Interbody Fusion of the Cervical Spine J Bone Jt Surg 44-A 1569-1587 1962

Acta orthop. Scandinav. XXXI 117-125 1964

From the Finsen Institute and the Radium Centre, Copenhagen, Dept. K
(Head: Johs. Meyer, M.D.)

# DORSAL HEMIVERTEBRA

By

POUL A. GJØRUP

A dorsal hemivertebra is taken to mean a vertebra in which the anterior half of the ossification centre in the body has failed to develop.

Another vertebral malformation, a cleft vertebra, has so many features in common with the dorsal hemivertebra when situated around the thoraco-lumbar junction that occasionally it is called a dorsal hemivertebra although this is not correct.

Apart from the bipartition, the body of the cleft vertebra has originally been similar to that of the other vertebrae, but presumably because of the distribution of pressure at this site in the spine the cleft vertebra is gradually pushed backward and takes on a wedge shape with the pointed end forward.

In the sagittal plane an X-ray film will show identical appearances in the two types of vertebral defect. A more or less wedge-shaped body with subluxation backward in relation to the adjacent vertebrae. This leads to an increased kyphosis or gibbus. The anterior edges of the adjacent vertebrae approach one another, may show compensatory growth and may at last be as close to each other as two normal vertebrae (*Gunt* 1957, *Junghanns* 1937). Incidentally, it is a characteristic feature that the intervertebral discs adjoining the dorsal hemivertebrae are normal.

Anteroposterior X-ray films will settle the doubt as to which vertebral malformation is concerned, especially when supplemented by tomography. In such a film the cleft vertebra will present itself as two symmetrical triangles on each side of the midline, the smallest angles facing and separated by a gap of varying size. As a whole the cleft vertebra is increased in width as compared with the neighbouring vertebrae (*Müller* 1931).

Cleft vertebrae may be situated at any level in the spine and often

co exist with other vertebral malformations block vertebrae etc However the most common sites are those mentioned above the upper lumbar and particularly the lower thoracic spine

The true dorsal hemivertebrae are most often localized in the first and second lumbar vertebra but may occur in the 3rd lumbar and the 11th or 12th thoracic vertebra It may be present as the only deformity (*Lindemann* 1931 *Bakke* 1935) and as a link in more widespread diseases such as achondroplasia (*Caffey* 1957) cretinism and chondrodystrophy (*Schinz, Baensch Friedl & Uehlinger* 1952 *Bracher* 1933 *Bauer* 1933) e g in one third of the cases with the Morquio type and even more often in gargoylism (*Fairbank* 1951) The dorsal hemivertebrae in the two types of chondrodystrophy exhibit characteristic variants of the wedge shape a pointed bill in the middle of the anterior aspect of the vertebra in Morquio s type in gargoylism the bill is blunt and situated low on the anterior aspect of the vertebra

*There is no doubt that dorsal hemivertebrae especially solitary ones* are rare but it is impossible to state the exact incidence It is important however to be aware of their existence and characteristics especially in order to avoid confusing them with spondylitis This justifies the publication of the following cases

## CASE REPORTS

*Case 1* Case rec K 19432 A male now 22 years of age As early as the age of 6 months his mother had noted that his back collapsed when he was to sit At first he was treated elsewhere as a case of rickets later as spondylitis Admitted here at the age of 14 months There was a non fixed arcuate gibbus at the level of the upper lumbar spine No direct or indirect tenderness no neurological abnormality and no abs ess formation E S R 5 mm Mantoux negative X rays of the spine *vide infra.* It was noted that the patient showed faint clinical sequelae of rickets He had a fairly large rectangular fontanelle but otherwise he was described as normal Radiography of all long bones failed to show any signs of rickets *but the metaphyses* were widened massive and condensed These changes were interpreted as signs of Møller Barlow s disease The patient had light treatment vitamins C and D and calcium A few months later the changes in the long bones had distinctly regressed The spine was treated by a plaster cast for 6 months After that time the gibbus was completely unchanged and so were the X ray appearances (cf Figs 1 and 2) The anteroposterior measurement of the body of the 2nd lumbar vertebra (v l II) was 15 mm while v l I measured 20 mm Its height was the same as that of v l I It was slightly wedged with a rounded forward directed point and slightl backward displaced especially in relation to v l III The bone structure was normal the body smooth with sharp contours and the intervertebral spaces normal On the anteroposterior view the vertebra looked completely normal The patient was discharged two months later



Fig 1



Fig 2

At the age of 18 the patient applied to another hospital He was now a farm hand and complained of backache of many years duration Again the arcuate kyphosis on a level with v. I I II and III was noted Now it was somewhat fixed No other clinical abnormalities X ray examination (Figs 3 and 4) showed that the kyphosis which had been about 28 at the age of 18 months had now increased to about 52 v. I II had become somewhat more wedged the backward dislocation was unchanged. The height of the body was equal to that of v. I III its anteroposterior measurement 35 mm as compared with v. I III which was 50 mm The intervertebral spaces were normal There was no compensatory growth of v. I I or v. I III rather a flattening of the lower and upper anterior edges An unmistakable sign of the increased kyphosis was the finding that the minimum distance between v. I I and v. I III had not changed from the age of 18 months to the age of 18 years The anteroposterior view showed that there was not a qeustion of a cleft vertebra

Apart from retraining for another occupation he was not given any treatment

*Case 2* Case rec K 37750 A boy aged 1? years A strong family history of tuberculosis The patient had "pneumonia" at the age of one year and thereafter the Mantoux test was positive His mother noted a gibbus 7 months prior to admission and definitely claimed that it had not been present before that time She had also



Fig 3



Fig 4

noted that the patient had got into the habit of immobilizing his spine He complained of fatigue but not of pain No neurological abnormalities

The patient was admitted to another hospital where his disease was interpreted *as tuberculous spondylitis of v th X He was treated by chemotherapy and bed rest* later with a plaster corset and was transferred to us because of better facilities for education We found a non fixed gibbus (Figs 5 and 6) in the lower thoracic spine Radiographs supplemented by tomography in two planes (by a Polytome at the Frederiksberg Hospital Figs 7 and 8) showed a kyphosis of approx 50 on a level with v th X At the same site there was a left convex scoliosis of about 10 Laterals showed the body of v th X to be small and wedged with the pointed end forward Its anteroposterior measurement was about 23 mm as compared with the neighbouring vertebrae 35 mm while its height was the same as that of the neighbouring vertebrae There was a slight backward dislocation most evident in relation to v th IX and the pedicle seemed somewhat wider than on the adjacent vertebrae The bony structure was normal and the contours sharp and clear The facing anterior edges of v th IX and XI were somewhat flattened and the distance between them no greater than the distance between the anterior edges of v th XI and XII The intervertebral spaces adjoining the deformed vertebra appeared to be slightly narrowed However this was not apparent from the anteroposterior view which showed that v th X was a cleft vertebra of increased width and of butterfly shape The right half of the body was smaller than the left in accordance with the scoliosis There was distinct compensatory growth of v th IX (less distinct of v th XI) especially around the centre of the vertebra corresponding to the cleft in v th X The patient was treated by training the spinal muscles



Fig 5



Fig 6



Fig 7



Fig 8



*Fig 9*



*Fig 10*

*Case 3* Case rec 183042 A female aged 39 who presented herself because of another disease She was found to have abundant hairing on the back on a level with the lumbar spine She had not had backache and there was no abnormal kyphosis

X ray examination (Figs 9 and 10) revealed numerous vertebral deformities extending from v th X to v l V The v th X was wedged greatly backward displaced so that its anterior edge was 10 mm behind those of the neighbouring vertebrae although the measurement from before backward did not differ definitely from the neighbouring vertebrae Incidentally this also applied to the height It was impossible to asses the intervertebral spaces Marked compensatory growth of v th XI Anteroposterior view showed a cleft vertebra slightly increased in width

It was noted that other split vertebrae were present int al v l IV (not visible on the anteroposterior view) On the lateral view the v l IV is wedged it is true but not posteriorly displaced and definitely not of an appearance suggesting a dorsal hemivertebra If anything it would seem to come within the term wedged vertebra which had been used by several authors

## DISCUSSION

While in Case 1 the diagnosis is a true congenital dorsal hemivertebra Cases 2 and 3 are examples of the false type of dorsal hemivertebrae caused by the pressure upon cleft vertebrae

Case 3 did not give rise to diagnostic difficulties both owing to the

absence of acute symptoms and because of the numerous other vertebral malformations which immediately pointed into the right direction

In Case 2 on the other hand the allegedly acute onset of a gibbus and the possibility of infection led to a diagnosis of tuberculous spondylitis Not until tomography was done in anteroposterior cuts did the true nature of the disease reveal itself as this investigation clearly visualized the cleft vertebra and the marked compensatory growth of the adjacent vertebrae The explanation why the dorsal hemivertebra was not detected until the age of 12 years may be that the kyphosis has developed so gradually that nothing unusual was discovered until the boy started having other symptoms A sudden "collapse appears unlikely as the compensatory growth of the neighbouring vertebrae must have been going on for a long time

In Case 1 there was also a suspicion of tuberculous spondylitis but owing to the normal structure and sharp outlines of the vertebra and the normal intervertebral space this diagnosis could not be confirmed Another distinctive factor was the backward subluxation which is an important diagnostic criterion The appearance of the other vertebrae and the entire clinical picture showed that the dorsal hemivertebra was not a link in a more extensive disease *e g* chondrodystrophy

It was only in Case 1 that the development could be followed from the time (4 months of age) before the deformed vertebra had been subjected to weight bearing until a time when the spine had been exposed to great strain It is remarkable that the dorsal hemivertebra developed and grew to exactly the same extent as the adjacent vertebrae Only a slight increase in the wedging was noted simultaneously with a marked increase in the kyphosis

If the other two patients had been examined at the age of 4 months it must be assumed that their cleft vertebrae viewed from the lateral aspect would have presented an appearance almost identical with that of the other vertebrae

The kyphosis in Case 2—the 12 year old boy whose back can hardly have been subjected to any major strain—was equally severe as in Case 1 the 22 year-old farm hand This indicates that it is the movements of the spine which lead to increased kyphosis rather than actual weight bearing due to heavy work The explanation that Case 3 had not developed kyphosis must be the simultaneous development of block vertebrae

The aetiology of the vertebral malformations is unknown As a rule

a defect in the notochord is held responsible The defect which leads to the formation of cleft vertebrae is developmentally earlier than that which causes a dorsal hemivertebra as the fusion of the originally two hemilateral primordia of the vertebral body occurs before the ossification centres start their development *Junghanns* assumed that the dorsal hemivertebra arose owing to the absence of the primordium of the anterior one of the two central ossification centres However if it is assumed that only one ossification centre is present (*Schin. et al*) the mechanism of the defect would sooner be failure of vascular ingrowth from the anteerior aspect

Familiar occurrence of dorsal hemivertebrae has been reported especially in chondrodystrophy (*Bracher*) and only once in the absence of other skeletal deformities (*Bauer*)

The importance of a really detailed X ray investigation of unusual vertebral malformations is greatly emphasized by the present case histories It is important to avoid unnecessary prolonged treatment and to advise the patients at an early stage regarding future occupation or possibly a change of occupation

## SUMMARY

Two types of dorsal hemivertebra are described a true type due to failing development of the anterior part of the ossification centre of the vertebral body and another type due to increasing deformation of a cleft vertebra Both types are localized around the thoraco lumbar junction and usually lead to marked kyphosis Three cases are reported and the differential diagnosis is discussed

## RESUME

Il existe deux types de demi vertebres dorsales un vrai du au manque de developpement de la partie anterieure du noyau osseux du corps vertebral et un autre du a la deformation grandissante d une vertebre fendue Les deux types sont localises dans la region de transition thoraco lombaire et menent en regle generale a une grave cyphose Trois cas sont examines et il est discute du diagnostic differentiel

## ZUSAMMENFASSUNG

Es gibt zwei Typen von dorsalen Halbwirbeln eine echte der eine manglende Entwicklung der vordersten Teiles des Wirbelkorper

knochenkernes zu Grunde liegt und eine andere die durch zunehmende Deformierung eines Spaltewirbels hervorgerufen wird Beide Arten lokalisieren sich in der Gegend des thorako lumbalen Überganges und fuhren in der Regel zu schwerer Kyphose Drei Falle werden dargestellt und die Differenzialdiagnose wird besprochen

## REFERENCES

*Bakke S N* Mi dannelser og utviklingsanomalier i hvirvelsøilen Bergen Fide p 14 1935

*Bauer H* Uber angeborene Wirbelsaulenmi sbildungen insbesonders angeborene Kyphosen *Z* orthop Chir *58* 355 1933

*Brecher M* Chondrodystrophia congenita tarda *Z* orthop Chir *58* 503 1933

*Caffey J* Pediatric X ray Diagnosis Chicago Year Book Publi hers p 1010 1957

*Fairbank T* An Atlas of General Affections of the Skeleton Edinburgh Livingstone p 174 1951

*Gunt F* Die Kyphose im Jugendalter Stuttgart Hippokrates Verlag p 32 1957

*Junghanns H* Die Fehlbildungen der Wirbelkorper Arch orthop Unfall Chir *38* 1 1937

*Linlemann K* Zur Kasuistik der angeborenen Kyphosen Arch orthop Unfall-Chir *30* 27 1931

*Müller W* Die angeb rene Gilbu bildung mit Wirbelk rperspaltung an der unteren Brustwirbels ule Arch orth p Unfall Chir *30* 319 1931

*Schin H R Baensch W F Friedl F & Lehlinger E* Lehrbuch der Rontgen diagnostik Stuttgart Thieme (2 Band 2 Teil) 1952

Acta orthop Scandinav XXXV 126–131 1964

From the Department of Surgery (Head B Chr Brynjulfsen) Fylkessjukehuset
(The County Hospital) Odda Norway

# TENDINITIS CALCAREA SUPRASPINATI

## *41 Operated Cases*

*By*

OTTAR HEGGO

Opinions are divided in respect to the treatment of tendinitis calcarea supraspinati In acute cases surgery has its adherents More reserve seems to be displayed in the case of chronic manifestations (*Bosworth* 1941 *Moseley* 1947 *Malm* 1955) However *Bruusgaard* (1952) has reported good results of surgery

The patients of the present series were treated by a simple surgical procedure The results were analysed and particular interest was devoted to patients with a relatively long duration of symptoms

### MATERIAL AND METHOD OF OPERATION

The series comprised 38 patients operated upon during the period 1951–1958 (Table 1) Three were treated on an out patient basis Three had operations on both shoulders Thus a total of 41 surgical procedures were carried out

The follow up study performed in March May 1959 included 37 patients as one patient did not attend and also did not answer a questionnaire All but 3 patients had a follow up period exceeding 6 months

Before the operation all the affected shoulders were studied by radiography The films showed in all cases but one an appearance which may be called a characteristic shadow At follow up films were not taken as a routine only a few random samples There was no case of a shadow like that mentioned above

Eight males and seventeen females underwent operation for a right sided lesion 4 and 6 respectively for a lesion on the left side Two males and one female had operations for right as well as left sided lesions

Two patients had the operations under general anaesthesia the others under local infiltration anaesthesia

TABLE 1

*Occupation and Sex Ratio of 38 Patients Operated upon for Tendinitis Calcarea Supraspinati (3 had Bilateral Operation)*

| Occupation | Males | Females | Total |
|---|---|---|---|
| Domestic work | | 20 | 20 |
| Manual work | 9 | | 9 |
| Office work | 5 | 4 | 9 |
| Total | 14 | 24 | 38 |

TABLE 2

*Type of Tendinitis Calcarea Supraspinati in 38 Operated Cases (3 Patients had Bilateral Operation)*

| Type | Males | Females | Total |
|---|---|---|---|
| Acute (I) | 8 | 5 | 13 |
| Chronic (II) | 4 | 10 | 14 |
| Chronic with exacerbation (III) | 4 | 10 | 14 |
| Total | 16 | 25 | 41 |

The patient lies supine and the best possible approach is obtained by supporting the affected shoulder on a cushion. A longitudinal skin incision is made above the greater tuberosity from the acromion and 4–5 cm into the distal direction. The deltoid muscle is split in the direction of the fibres. Care must be taken not to injure the axillary nerve. The sub deltoid bursa is opened. At the site of the prominence of the bursa floor which represents the focus, an incision is done including the underlying tendon sheath. Any material which is not evacuated spontaneously after this incision is emptied out by a spoon. The wound is closed by a couple of interrupted catgut sutures into the muscular fascia and sutures into the skin.

On the following day the patients are started on active exercises. The majority of the present patients had a normal range of movement in the affected limb 4–8 days after the operation. A few patients who had a particularly long history and whose ability to move the arm seemed greatly reduced were helped by passive stretching.

The majority of the Type I patients (Table 2) went back to work 8–10 days after the operation. A few of the groups domestic and office work started working in 4–8 days, two even earlier. The great majority

of Type II and Type III patients were working again at the end of 8–14 days while one patient was off work for 4 weeks allegedly because he had pain in the skin wound

Apart from a short lasting inflammatory condition of the skin wound in one patient no complications occurred

## RESULTS

The results of the follow up study are stated in Table 3 The group of *excellent* results consists of patients who had no pain in the previously affected shoulder A *good* result signifies that the patients had less marked not annoying pain in the affected shoulder A *poor* result was recorded in one case a patient whose symptoms were unchanged In the excellent group 3 patients of Type II had more or less marked abnormal muscle tension in the shoulder and neck Two of these patients showed a limitation of abduction in the previously affected limb The same applied to one patient of Type III who also had a palpable muscular atrophy in the shoulder and upper arm on the affected side

During the period between the operation and the follow up 4 patients had developed symptoms of supraspinatus tendinitis on the contralateral side

TABLE 3

*Follow up Findings in 38 Patients Operated upon for Tendinitis Calcarea Supraspinati (3 had bilateral Operation)*

| | Result | | | Not examined | Total |
|---|---|---|---|---|---|
| | Excellent | Good | Poor | | |
| Acute (I) | 13 | | | | 13 |
| Chronic (II) | 12 | | 1 | 1 | 14 |
| Chronic with exacerbation (III) | 12 | 2 | | | 14 |
| Total | 37 | 2 | 1 | 1 | 41 |

## DISCUSSION

The described operative procedure is very simple only very slightly mutilating and causes the patient little pain It can be carried out under local anaesthesia

In acute cases this treatment results in prompt relief from pain The convalescence is short In the present series there were no signs of recurrences which is in keeping with the findings of others (*Moseley*)



Fig 1



Fig 2

Calcification of the supraspinatus tendon

Furthermore the investigation shows that the treatment is quite effective also in the *chronic* types there were also no signs of recurrences among patients with a relatively long duration of disease However one patient was not after examined

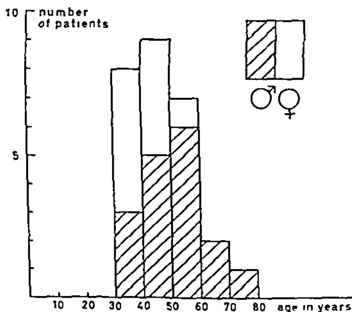



Fig 3

The present surgical treatment compares favourably with conservative therapy (*Arner Lindvall & Rieger* 1958 mainly roentgen therapy *Conventry* 1954 cortisone hydrocortisone therapy) This is evident also from the fact that more than half the patients with a long duration of symptoms had previously received roentgen therapy a number of them even several series in the course of some years Furthermore many of these patients had previously had other treatment as a rule various forms of physiotherapy Five patients with acute symptoms had previously been referred for roentgen therapy 2 had been treated by aspiration or attempts at aspiration of calcific material by the percutaneous route

Only relatively few patients had what may be called secondary changes in the previously affected shoulder restricted movements muscular atrophy or abnormal muscular tension Systematic training of function after the operation is presumably an important factor

## SUMMARY AND CONCLUSIONS

From 1951 to 1958 inclusive 38 patients with tendinitis calcarea supraspinati were treated surgically Three had operations on both shoulders making a total of 41 shoulders The results are reviewed

The calcific deposists were evacuated by a simple incision

In acute cases promt complete and permanent relief was obtained by this method as has been found by previous workers

It is apparent also from the analysis that in the chronic types surgery seems to be superior to conservative measures in respect to relief duration of treatment and early fitness for work There were no recurrences in the present series

Treatment must be directed at the entire shoulder an effort being made to obtain and retain a normal range of movements in the shoulder joint

## RESUME

Les resultats du traitement chirurgical de 38 malades souffrant de tendinitis calcarea supraspinati operés de 1951 à 1958 inclus ont ete reexaminees Dans 3 cas les deux épaules avaient ete operees ce qui donnait au total 41 epaules

Le depot calcifie a ete evacue par un procede simple une incision dans la direction des fibres tendineuses

Dans les cas aigus un soulagement prompt complet et permanent a

été obtenu par cette méthode comme on l'avait découvert antérieurement

Cette série montre par ailleurs que dans les cas de type chronique l'intervention chirurgicale semble supérieure au traitement conservateur tant par rapport au soulagement à la durée du traitement qu'à la capacité de reprendre rapidement le travail Il n'y a pas eu de récidive dans cette série

Le traitement doit être dirigé sur toute l'épaule un effort devant être fait pour obtenir et maintenir une étendue normale des mouvements de l'articulation de l'épaule

## ZUSAMMENFASSUNG

Die Ergebnisse der chirurgischen Behandlung von 38 Patienten mit Tendinitis calcarea supraspinati von 1951 bis 1958 wurden besprochen In drei Fällen wurden beide Schultern operiert was eine Gesamtzahl von 41 Schultern ergiebt

Die Kalkniederschläge werden mittels eines einfachen Vorgehens nämlich einer Inzision in der Richtung der Sehnenfasern ausgeräumt

In akuten Fällen wird eine rasche vollständige und dauernde Heilung wie sie auch von früheren Autoren gefunden wurde mit dieser Methode erzielt

Diese Reihenfolge zeigt weiterhin dass in chronischen Fällen der chirurgische Eingriff sowohl hinsichtlich der Schmerzerleichterung der Behandlungsdauer als auch der frühzeitigen Arbeitsfähigkeit den konservativen Massnahmen überlegen ist In diesem Materiale gab es keine Rückfälle

Die Behandlung muss die ganze Schulter ins Auge fassen indem man darauf achtet eine normale Beweglichkeit im Schultergelenke zu erzielen und festzuhalten

## REFERENCES


*Arner O Lindholm A & Rieger A* Calcific tendinitis of the Shoulder joint Acta chir Scandinav *115* 319 1958

*Bosworth B M* Calcium deposits in the shoulder and subacromial bursitis J A M A *116* 2477 1941

*Bruungaard Chr* Supraspinatustendinit T norske lægeforen 9? 97 19?

*Coventry M* The use of cortisone and hydrocortisone in treatment of painful shoulder Proc Mayo Clin 29 58 19?4

*Malm P* Indications for operative treatment of tendinitis calcarea Acta chir Scandinav *103* 44 1935

*Moseley H F* Shoulder lesion Springfield Charles C Thomas 1947

Acta orthop. Scandinav. XXXIV, 132–137, 1964

From the Orthopaedic Clinic, Linköping, Sweden (Head: Ragnar Magnusson, M.D.)

# OBSERVATIONS OF OPERATIVE TREATMENT OF RESIDUAL DISLOCATIONS OF THE SHOULDER

*By*

STIG WILLNER

Occasional dislocations of the shoulder occur primarily in older persons—the age group 50–60, while residual dislocations are to be found almost without exception in younger persons between the ages of 20–30 and in the latter case usually in men. The residual dislocations are in most cases found to be anterior—according to *Neugebauer* up to 98 per cent.—Our material, 42 cases, consists entirely of anterior dislocations of the shoulder. The initial dislocation in the residual cases is caused by a trauma, in several cases a surprisingly slight one. This has given rise to the thought that these patients must have one or more predisposing factors which facilitate the dislocation. This has, however, not yet been fully clarified.

But there is general agreement that the predisposition of the residual cases is due to certain changes of the joint when first dislocated. In 1890 *Broca & Hartman* spoke of the gleno-labral detachment as a deciding factor. Its occurrence is frequent and *Adams* mentions its appearance in 85 to 90 per cent. Another finding observed in radiographs is the fracture of impression situated on the dorso-lateral sector of the humerus. This fracture is considered by many to be the essential lesion. (According to *Adams* a frequency of 80–85 per cent.) Injuries and stretching of the capsular ligament also seem to reduce the stability of the joint. Another finding observed in the arthrography of these patients is the depression of the anterior rim of the cavity—a lesion arising only simultaneously with detachment of the labrum. This observation has been made by many – it is mentioned by *Adams* in 1948 and later by several others (*Albik* 1951 and *Moseley* 1961 in his book on residual dislocations of the shoulder.) However, according to certain researchers

it occurs only sporadically whereas others consider it more a consequence of the dislocation than a predisposing factor.

A follow up of operated residual dislocations of the shoulder during a ten year period at the Orthopaedic Clinic—Centrallasarettet in Lin-köping (Sweden)—has allowed us to study the above mentioned operative finding and we have tried to put it into relation to information from records gathered from a) journals kept during the actual period of treatment and b) question forms sent by us to these patients (autumn 1961). Our material consists of 42 operated cases; we have received thorough answers from 31 patients. All operations were performed according to the Eden-Hybinette method with a bone graft intraarticularly fixed in a periosteal pocket in front of the anterior cavity rim. A slight modification was made—instead of the usual comma formed graft a straight wedge formed one was used. Stress is laid upon the fact that the upper part of the graft is level with the intact cavity rim. The bone graft has healed in all cases.

TABLE 1

| | Many dislocations >5 | Few dislocations <5 |
|---|---|---|
| Cases with significant depression of the edge of the cavitas glen. | 31 | 4 |
| Slight depression | 1 | 3 |

TABLE 2

| | Easily dislocated | Not easily dislocated |
|---|---|---|
| Cases with significant depression of the edge of the cavitas glen. | 17 | 3 |
| Slight depression | 0 | 4 |

TABLE 3

| | Able to reduce the dislocation himself | Unable to reduce the dislocation himself |
|---|---|---|
| Cases with significant depression of the edge of the cavitas glen. | 13 | 6 |
| Slight depression | 1 | 3 |

Of our 42 operated patients 10 were women 32 men Their average age at the time of the initial dislocation was 22 for men 21 for women 24 The youngest was a girl of 5—the oldest a man of 49 Of the 31 cases which we have been able to follow up during a period of 1–10 years there have been no recurrences Of the 31 patients examined after the operation 22 stated that they felt no pain stiffness or soreness of the shoulder after the operation They had all been able to resume their regular work various recreations and sports 8 had minor irritations or disturbances which occurred however extremely sporadically They were occasionally due to new and strenous movements but did not affect their working capacity or hamper them in any way The general complaint that of a relatively mild pain and soreness was of a temporary nature Only in one of the cases—a man aged 49 at the time of the initial dislocation—was there a more pronounced pain and soreness with exertion—foremost heavy lifting Of the 9 cases with subjective symptoms of irritation 2 had not regained full range of shoulder movement compared with the undamaged shoulder External rotation and movements backwards were limited in only 1 of the other 22 cases subjectively free from disturbances This impairment however was insignificant— and according to the patient—of no importance

Finally I should briefly like to discuss our examination of the occurrence of the depression of the bony glenoid rim In our material of 42 operated cases a more or less significant depression was noted in 39 cases There is no data on 2 of the remaining 3 and in the third case both the glenoid labrum and cavity were intact In 4 of the 39 patients the lesion was very slight—though fully able to be diagnosed In the remaining 35 cases the lesion was both noticeable and palpable The lesion was described as serious in 7 cases—it then stretched down to the joint cavity We found that the patients who had a significant depression had in their records more dislocations of the shoulder than those whose depression was slight (Table 1) We also found that the shoulder was more easily dislocated if there was a significant depression than if there was a slight lesion (Table 2) A third observation was that it was easier for patients with a significant lesion of the cavity to reduce their dislocation themselves than for those with a very slight lesion (Table 3) It would be of great interest to see if the lesion of the cavity occurred at the time of the initial dislocation and then remained stationary or if the depression increased with new recurrent dislocation We have however not yet been able to find a satisfactory answer to this question It appears however as if the lesion of the cavity in patients operated

*upon within a relatively short period of time after the initial dislocation* is of the same extension and severity as in those who have had their injury for several years This could be interpreted thus a lesion of the anterior rim of the cavity occurred simultaneously with detachment of the gleno-labrum at the initial dislocation of the shoulder It could perhaps also be considered a fracture of impression similar to the one of the dorso lateral sector and of the same origin We have not found any convincing arguments for this theory

The good results obtained from the Eden Hybinette method should *also support the opinion that the main factors for the residual disloca*tions of the shoulder are to be found in the anterior part of the cavitas glenoidale in other words in the detachment of the labrum glenoidale and the lesion of the cavity The principle of the above mentioned method is as we know a reinforcement of the anterior part of the cavity

It is therefore evident that the depression of the bony rim plays a far greater part in the understanding of the rather complex matter of the dislocation of the shoulder than has earlier been believed

## SUMMARY

Following the first traumatic dislocation recurrent dislocations take place in a number of cases Opinions differ as to the genesis of such dislocations An observation made by several surgeons but not directly connected with the cause of the recurrent shoulder joint dislocations is that the anterior rim of the cavity is pressed down and that this can be so pronounced that it reaches down to a level with the bottom of the cavity

A follow up examination was made of a surgical series of recurrent shoulder dislocations Here it was found that the greater the number of dislocations recorded in the case history the more pronounced was the downward pressure of the anterior rim of the cavity A more marked downward pressure was observed to a larger extent in patients who could reduce their shoulder joints themselves

The author considers that the downward pressure of the anterior rim of the cavity is a decisive factor in the manifestation of recurrent shoulder joint dislocations

## RÉSUMÉ

Après une première luxation de nature traumatique il se produit des récidives dans bien des cas Les avis sont partagés sur la genèse de

celles-ci. Une chose a été observée par bien des médecins sans être mise en rapport direct avec la cause des luxations récidivantes de l'épaule, c'est la pression vers le bas du bord antérieur de la cavité qui peut être si prononcée qu'il atteint le niveau du fond de la cavité.

Un réexamen de malades opérés pour luxations récidivantes de l'épaule a fait ressortir que plus le nombre des luxations est élevé dans l'anamnèse, plus la pression vers le bas du bord antérieur de la cavité est prononcée. Une pression plus marquée a été constatée chez les malades pouvant eux-mêmes remettre leur articulation de l'épaule en place.

L'auteur estime que la pression vers le bas du bord antérieur de la cavité a été un facteur décisif pour l'apparition des luxations récidivantes de l'articulation de l'épaule.

## ZUSAMMENFASSUNG

Nach der ersten traumatisch bedingten Luxation treten in einem Teil der Fälle rezidivierende Luxationen auf. Über die Genese der zuletzterwähnten bestehen geteilte Meinungen. Ein Umstand, der von mehreren beobachtet wird, der aber nie in direkte Verbindung mit der Ursache für die rezidivierende Schultergelenksverrenkung gebracht wird, ist die Hinunterpressung des vorderen Randes der cavitas glenoidalis, die so ausgeprägt sein kann, dass sie den Boden der Cavitas erreicht.

Eine Nachuntersuchung eines operierten Materiales von Schultergelenksverrenkungen wurde vorgenommen. Anlässlich dieser fandt man, dass je häufiger Luxationen in der Anamnese angegeben werden, desto mehr ist die Hinunterpressung des vorderen Cavitasrandes ausgeprägt. Eine besonders ausgeprägte Hinunterpressung wurde in grösserem Ausmasse bei Patienten beobachtet, die ihre Verrenkung selbst reponieren konnten.

Der Verfasser ist der Meinung, dass die Hinunterpressung des vorderen Cavitasrandes ein ausschlaggebender Faktor bei der Entstehung der rezidivierenden Schultergelenksverrenkung ist.

## REFERENCES


1. *Adams, J. C.*: Recurrent Dislocation of the Shoulder. J. Bone Jt Surg. *30-B*, 26, 1948.
2. *Alick, I.*: 3 tillfaller av habituell skulderluksasjon operert a.m. Hybinette. Nord. Med. 45, 96, 1951.

3 *Bankart A S B* Discussion on Recurrent Dislocation of the Shoulder J Bone Jt Surg *30-B* 46 1948
4 *De Palma A F* Surgery of the Shoulder 1950
5 *Lamk K* Habitual Shoulder Luxation Acta orth Scandinav 3 ?51 1961
6 *Moseley H F* Recurrent Dislocation of the Shoulder 1961
7 *Neugebauer H* Willkurliche Schulterluxation nach vorne ruckwarts und unten Arch orthop Unfall Chir 53 Band 2 Heft 14? 1961

Acta orthop Scandinav XXXI 138-148 1964

From the Department of Surgery (Head Knut Bie M D ) Haugesund sykehus Haugesund Norway (Former Head Kristian Stray M D Professor of Surgery University of Bergen )

# SKIN TRACTION TREATMENT OF SUPRACONDYLAR FRACTURES OF THE HUMERUS IN CHILDREN

*A Ten Year Review*

*By*

ROLF HAGEN

Supracondylar fractures of the humerus are the most common elbow injuries in children The treatment of these fractures when badly displaced remains a difficult fracture problem in childhood Different closed reduction methods of treatment have been recommended (*Bohler* 1943 *Palmer* 1962 *Watson Jones* 1960) However some surgeons have advocated various forms of osteosynthesis such as Rissler nails (*Holmberg* 1945 *Windfeld & Pilgaard* 1961) or Rush pins (*Rastima & Kortlila* 1960)

The treatment by permanent skin traction was originally recommended by *Bardenheuer* in 1889 (*Borchgrevink* 1908) with the elbow in right angled position *Borchgrevink* constructed a special splint and the traction was accomplished in the direction parallel with the normal forward tilt of the lower humeral epiphysis *Ingebrigtsen* in 1908 intended to avoid the splint and advocated a modification of the skin traction in smaller children In the bedridden patient the extremity is suspended overhaed by means of skin traction in three directions Later the adhesive tape traction method in various forms has been recommended by other authors (*Dunlop* 1939 *Malti* 1931 *Siris* 1938)

The following study endeavours to evaluate the late results of two different conservative methods of treatment One group of severely displaced fractures was treated with *Ingebrigtsen* s skin traction while another similar group of fractures was immobilized in a posterior plaster splint with a collar and cuff sling a method recommended by *Watson Jones* and *Palmer*

In both groups the reduction was performed under general anaesthesia with the forearm in pronation Fluoroscopy through the mobile image amplifier was used only intermittently to verify the position of the fragments

The overhead pulle adhesive suspen ion was applied as suggested by *Ingebrigtsen* (Fig 1) Tracti n to the pr nated forearm to keep the distal fragment in position (retenti n l ad 1 3½ kg) countertraction to the upper arm to pull the proximal fragment p steri rly (l ads ½-1 kg) and vertical traction parallel with the longitudinal axis f the upper arm (½-3 kg) depending on the degree of dislocation the obliquit of the fracture line and the age of the child The average flexion degree of the elb w was 40 (range 25-70) The skin traction was continued for an average of 21 days whereas the duration of imm bilization of the posterior plaster splint cases average l 28 days

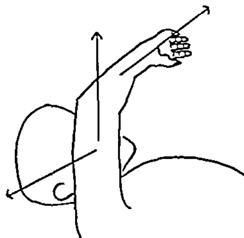


*Fig 1*
Ing brigt en kin tracti n

THE SERIES

During the period 1951 1960 in all 70 patients with supracondylar fractures were admitted to the Department 60 per cent of the fractures were in boys and 40 per cent in girls 78 per cent were between the ages of 3 and 10 years the average age was 6 years (range 1 14)

For purposes of comparison with other series the fractures have been classified into 4 types according to the degree of displacement d tected on roentgen examination a sy tem originally suggested by *Holmberg* (Table 1)

TABLE 1
*Types of Fractures*

| | | No | ♂ | ♀ | Ext. typ. | Flex. typ. |
|---|---|---|---|---|---|---|
| Type I | Fractures without displacement | 4 | 2 | 2 | | |
| Type II | Fractures with sideways and/or dorsal (ventral) displacement | 16 | 11 | 5 | 16 | |
| Type III | Fractures with rotational displacement, possibly with sideways and angulatory displacement | 17 | 5 | 12 | 12 | 5 |
| Type IV | Fractures with complete displacement (no contact between the fragments) | 33 | 24 | 9 | 31 | 2 |
| | Total number of fractures | 70 | 42 | 28 | 59 | 7 |

5 of the extension type fractures belonging to Type IV were compound and 1 of the Type III fractures was a comminuted Y fracture. Type III and Type IV combined (severely displaced fractures) made up 70 per cent of the total number of fractures. The displacement of the distal fragment in the four different types is given in Table 2.

TABLE 2
*Displacement of the Distal Fragment*

| | Rotational displacement | | | Side displacement with or without angulation | | |
|---|---|---|---|---|---|---|
| | Inwards | Outwards | No | Radial | Ulnar | No |
| Type I | | | | | | |
| Type II | | | | 8 | | 8 |
| Type III | 12 | 5 | | 10 | 5 | 2 |
| Type IV | 26 | 5 | 2 | 17 | 16 | |

TREATMENT

The treatment applied in the four different types is shown in Table 3. The flexion type fractures were treated as follows: 4 by skin traction in 25 of elbow flexion and 3 by a posterior plaster splint with the elbow acutely flexed.

In general the fractures treated by skin traction were more severe than those treated in the acute angled elbow position. The former group included 5 compound fractures and two thirds of the fractures with an

oblique fracture line in lateral view. Manipulative reduction had to be repeated once in 16 patients and twice in 3 patients belonging to Type III and IV. Secondary displacement occurred in 26 per cent of the cases mainly among the posterior plaster splint cases. In 10 patients treated by *skin traction manipulative reduction* and a plaster cast or a posterior plaster splint were tried primarily without success. Minor displacements persisting after the primary reduction disappear as a rule during 10–12 days with sustained skin traction by which time roentgenograms usually show callus. The average age incidence in the skin traction group was 6.4 years (range 2–13) and in the posterior plaster splint group 6.1 years (range 1–11).

TABLE 3

*Method of Treatment in the Four Different Types of Fractures*

| | Type I | Type II | Type III | Type IV | Total |
|---|---|---|---|---|---|
| Manipulative reduction and skin traction | | | 8 | 18 | 26 |
| Manipulative reduction posterior plaster splint and sling (elbow acute angle) | 4 | 16 | 9 | 15 | 44 |
| Total | 4 | 16 | 17 | 33 | 70 |

The primary results, *i.e.* the results at the end of the treatment judged from the roentgenograms, were graded into the following groups as presented in Table 4.

TABLE 4

*Primary Results*

| | | *Perfect anatomical or [illegible] without displacement* | Slight [illegible] rotational displacement | *Reduction* unsatisfactory displacement | Total |
|---|---|---|---|---|---|
| Skin traction | Type III | 3 } 61.5 | 5 | | 8 |
| | Type IV | 13 | 4 | 1 | 18 |
| Posterior plaster splint | Type I | 4 | | | 4 |
| | Type II | 13 | 3 | | 16 |
| | Type III | 4 } 58.3 | 3 | 2 | 9 |
| | Type IV | 10 | 2 | 3 | 15 |
| Total | | 47 | 17 | 6 | 70 |

## COMPLICATIONS

Judged from the literature complications appear to be relatively common (*Böhler*, *Lipscomb & Burleson* 1955, *Watson Jones*).

In the present study there was an incidence of 17 per cent of neural and vascular injuries. The radial nerve was injured in 8 cases, the median nerve in 2 cases and the ulnar nerve in 1 case. They commonly occurred among Type IV extension fractures. The injury of the ulnar nerve was encountered in a Type III flexion fracture. 6 of the cases recovered completely during the hospitalization, whereas the remaining 5 nerve injuries disappeared during 2–6 months.

The radial pulse was absent in 7 cases. All of these were treated by *Ingebrigtsen*'s skin traction and the radial pulse returned after the reposition. Volkmann's ischaemic contracture has not developed in any of the cases.

## FOLLOW-UP STUDIES

All the 70 patients were re-examined clinically and roentgenologically from 2 to 11 years after the fracture, the average observation time being 6.5 years. Changes in the normal carrying angle were observed in 23 (32.9 per cent) of the 70 patients examined (Table 5). A varus type change was nearly twice as frequent as increased valgidity. The change in carrying angle occurred in 34 per cent of those treated by skin traction, and in 58 per cent of an equivalent group treated by acute-angled elbow position. Perfect anatomical results were achieved in 67 per cent of the whole material.

TABLE 5
*Changes in Normal Carrying Angle at Follow-up*

| | No change | Reduced | Increased | Total | Degree of angle | |
|---|---|---|---|---|---|---|
| | | | | | Max. | Average |
| Skin traction | 17 | 6 | 3 | 26 | 10 | 6.6 |
| Posterior plaster splint | 30 | 9 | 5 | 44 | 30 | 8.5 |
| Total | 47 | 15 | 8 | 70 | | |

## FINAL RESULTS

On clinical follow-up the state of the injured elbow was classified according to the criteria originally applied by *Holmberg*.

1 *Satisfactory Results*

a) Ideal No complaints, varus or valgus deformity of 0–5°, normal range of motion

b) Good Varus or valgus deformity of 6–10°, limitation of flexion extension of 0–10°, and no impairment in rotation

2 *Unsatisfactory Results*

Changes surpassing these limits

The final results are listed in Table 6. *All the 26 skin traction cases presented a satisfactory result*, while an equivalent group of 24 patients treated by a posterior plaster splint showed 3 unsatisfactory results. One of these cases was almost ideally reduced on admittance, however, the patient was dismissed on the second day after reduction and a severe secondary ulnar tilt of the distal fragment occurred. In a second case the fracture was apparently combined with severe capsular and ligamentous damage and healed with marked volar and ulnar angulatory displacement. Lastly, an extension fracture of a 3 year old boy was obviously not properly reduced and healed with rotational and angulatory displacement. In the flexion fractures 6 had ideal and 1 a good result.

TABLE 6
*Final Results*

| Type | Treatment | Satisfactory | | Unsatisfactory | Total |
|---|---|---|---|---|---|
| | | Ideal | Good | | |
| I and II | Posterior plaster splint | 20 | | | 20 |
| III | Skin traction | 7 | 1 | | 8 |
| | Posterior plaster splint | 5 | 3 | 1 | 9 |
| IV | Skin traction | 15 | 3 | | 18 |
| | Posterior plaster splint | 12 | 1 | 2 | 15 |
| Total | | 59 | 8 | 3 | 70 |

## COMMENT

Table 7 gives an impression of the relation between the adequacy of the reduction and the end result.

A persistent sideways or slight rotational displacement causes little or no loss in the carrying angle. On the other hand an angulatory

displacement will inevitably produce such a change. It is notable that in none of these cases was a valgus or varus angulation corrected by remodelling, not even in the earlier mentioned case of the 3 year old boy. *Smith* (1960) showed experimentally by a transverse supracondylar osteotomy that only varus or valgus angulation changed the carrying angle. This did not occur with sideways displacement or with an internal rotation of less than 15° of the distal fragment. However any degree of rotation with an oblique fracture line in the lateral view will produce tilting of the distal fragment. *Mann* (1963) analysed 22 children with severe supracondylar fractures and concluded that cubitus varus deformity was caused by medial angulation of the distal fragment.

TABLE 7
*Relation between Primary and Final Results*

| Primary result | | Final result | | |
|---|---|---|---|---|
| | | Ideal | Good | Unsatisfactory |
| Ideal or almost ideal | 47 | 47 | | |
| Sideways and slight rotational displacement | 17 | 12 | 5 | |
| Rotational and angulatory displacement | 6 | | 3 | 3 |
| Total | 70 | 59 | 8 | 3 |

Osteosynthesis or a traction arrangement prevents this tendency to angulatory displacement. However most authors admit that operative procedure may be technically difficult and is often followed by decreased range of movement and some residual stiffness. *Hoyer* (1952) reported good results in his series treated by skeletal traction on a Semb's abduction splint. Meanwhile several surgeons warn against the use of skeletal wire traction in the immediate proximity of the elbow joint. Such a procedure is uncomfortable and also unnecessary because the needed amount of traction to compensate the forces of redislocation is comparatively small. Skin traction of the acute angled elbow position is in this respect sufficient.

Concerning the treatment *ad modum* Ingebrigtsen it should be stressed that the elastic adhesive tape properly applied will not compromise the neurovascular structures in the front of the elbow joint. This is advantageous for treating badly displaced fractures with considerable swelling. Furthermore the patient can actively exercise the elbow within the confines of the dressing during the period of immobi-

lization The absorption of haematoma and synovial exudate is stimulated and the tendency to stiffness of the elbow and muscular atrophy is prevented The return of function is thus hastened and the functional late results seem favourable

The results obtained in the present series among Type III and IV fractures have been compared with *Holmberg's* operatively treated group and *Høyer's* group treated by skeletal traction (Table 8) The indications for the various methods of treatment have in all probability been the same In comparing these groups it is evident that *Ingebrigtsen's* method discloses a higher percentage of superior results

TABLE 8

*Comparisons between the Final Results of Osteosynthesis Skeletal and Skin Traction and Treatment a m Watson-Jones*

| | Satisfactory | | Unsatisfactory | Total |
|---|---|---|---|---|
| | Ideal | Good | | |
| Osteosynthesis (Holmberg) | 28 | 14 | 8 | 50 |
| Skeletal traction (Høyer) | 14 | 10 | 2 | 26 |
| Skin traction (Hagen) | 22 | 4 | | 26 |
| Acute angled elbow flexion (Hagen) | 17 | 4 | 3 | 24 |

## SUMMARY AND CONCLUSION

70 children with supracondylar fractures of the humerus were reexamined at an interval from 2 to 11 years after the injury Severely displaced fractures constituted 70 per cent of the whole material and were mainly treated by acute angled elbow flexion and skin traction

As a rule the fragments separated by a transverse fracture line extending along the boundary between cartilage and bone are easily reduced and retained by acutely flexed elbow The triceps tendon keeps the distal fragment in position the fracture surfaces are broad and the tendency to secondary displacement is small

In some cases however this treatment does not suffice Those separated by an oblique fracture line at a higher level in the olecranon fossa are frequently more difficult to reduce and often slip during the postreduction period These fractures require skin traction as their primary definitive treatment In all compound and comminuted fractures and in cases with vascular complications skin traction is the treatment of choice

Growth disturbance as a cause of change in the carrying angle was not suggested in any of the cases. From this material the prime reason for these changes seems to be disalignment of the fragments.

*Ingebrigtsen*'s skin traction method was followed by minimal loss of function and the smallest percentage of carrying angle changes. This method of management has proved practical and has a successful effect on the pathological process following a supracondylar fracture.


## RÉSUMÉ

70 enfants avec fractures supracondylaires de l'humerus ont été réexaminés au bout d'une période entre 2 et 11 ans après la lésion. Des fractures graves avec déplacement constituaient 70 pour cent de l'ensemble du matériel d'observation et avaient principalement été traitées par flexion du coude à angle aigu et traction de la peau.

En règle générale les fragments séparés par une fracture transversale longeant la ligne de démarcation entre le cartilage et l'os sont plus faciles à réduire et à maintenir en place dans la position de flexion du coude à angle aigu. Le tendon du triceps maintient le fragment distal en place, les surfaces de la fracture sont larges et la tendance au déplacement secondaire est faible.

Dans certains cas, cependant, ce traitement n'est pas suffisant. Lorsque les fragments sont séparés par une fracture de ligne oblique à un niveau plus élevé de la fosse olécranienne, la réduction est souvent difficile et les fragments se séparent parfois pendant la période de post-réduction. Ces fractures exigent une traction de la peau comme traitement primaire définitif. Dans toutes les fractures compliquées et broyées et dans les cas avec complications vasculaires, la traction de la peau est le traitement de choix.

Des troubles de la croissance comme une cause des modifications de l'angle du coude n'ont été présumés dans aucun de ces cas. La cause primordiale des changements semble être un désalignement des fragments.

*La méthode de traction de la peau d'Ingebrigtsen* a été suivie avec une perte fonctionnelle minime et le pourcentage le moins élevé de modifications de l'angle du coude. Cette méthode s'est montrée pratique et a eu un heureux effet sur le processus pathologique consécutif à une fracture supracondylaire.

## ZUSAMMENFASSUNG

70 Kinder mit suprakondylaren Humerusbrüchen wurden nach einem Zeitraum von 2 bis 11 Jahren nach der Verletzung wiederuntersucht. Hochgradig verschobene Brüche machten 70 Prozent des Gesamtmateriales aus und wurden hauptsächlich mittels Hautextension bei spitzwinkelig gebeugtem Ellbogen behandelt.

In der Regel können die Fragmente, welche durch eine transverse Bruchlinie gesondert sind, die sich entlang der Grenze zwischen Knorpel und Knochen ausdehnt, leicht reponiert und bei spitzwinkelig gebeugtem Ellbogen in Stellung gehalten werden. Die Tricepssehne hält das distale Fragment in Stellung, die Bruchflächen sind weit und die Neigung zur sekundären Verschiebung ist gering.

In einigen Fällen jedoch genügt diese Behandlung nicht. Jene, die durch eine schräge Bruchlinie, etwas länger proximal in der fossa olecrani, getrennt sind, sind oft schwieriger zu reponieren und gleiten oftmals sekundär. Diese Brüche erfordern Hautextension als primäre und endgültige Behandlung. Bei allen komplizierten und Splitterbrüchen ist die Hautextension die Methode der Wahl. Wachstumsstörung als Ursache einer Veränderung des Achsenwinkels war in keinem der Fälle angedeutet. Aus diesem Material geht hervor, dass der vorherrschende Grund für derlei Veränderungen eine schlechte Anpassung der Bruchstücke war.

Ingebrigtsens Hautextensionsmethode hatte einen sehr kleinen Funktionsverlust und den geringsten Prozentsatz von Veränderungen des Achsenwinkels zur Folge. Diese Behandlungsmethode hat sich als praktisch erwiesen und hat eine erfolgreiche Wirkung auf den einer suprakondylaren Fraktur folgenden pathologischen Prozess.

## REFERENCES

*Bardenheuer, B.*: Die permanente Extensionsbehandlung. Stuttgart, 1889. (Referred to by Borchgrevink.)

*Borchgrevink, O.*: Ambulatorische Extensionsbehandlung der oberen Extremität. Von Gustav Fischer, Jena 1908.

*Böhler, L.*: Die Technik der Knochenbruchbehandlung. Maudrich, Vienna, 1943.

*Dunlop, J.*: Transcondylar fractures of the humerus in childhood. J. Bone Jt Surg. 21, 59, 3 1939.

*Holmberg, L.*: Fractures in the distal end of the humerus in children. Acta chir. Scandinav. Suppl. 103, 1945.

*H[illegible]r, A.*: Treatment of supracondylar fracture of the humerus by skeletal traction in an abduction splint. J. Bone Jt Surg. 34-A, 6?3-63?, 195?.

*Ingebrigtsen, R.*: Personal communication, 196[illegible].

*Lipscomb P R & Burleson R J* Vascular and neural complications in supracondylar fractures of the humerus in children J Bone Jt Surg 37-A 487-492 1955

*Mann T S* Prognosis in supracondylar fractures J Bone Jt Surg 45-B 516 522 1963

*Matti H* Zur Behandlung der suprakondylären Humerusfraktur Chirurg 9 41 50 1937

*Palmer I* Nordisk Lærebog i kirurgi Munksgaard Copenhagen pp 810-813 1962

*Rastima R O & Korttila K* Rush pin vid distala humerusfrakturer Nord Med 63 653-655 1960

*Siris I F* Supracondylar fracture of the humerus An analysis of 330 cases Surg Gynec Obstet 68 201-222 1938

*Smith L* Deformity following supracondylar fractures of the humerus J Bone Jt Surg 42-A 235 252 1960

*Watson Jones R* Fractures and joint injuries Livingstone Edinburgh and London pp 524-532 1960

*Windfeld P & Pilgaard S* Osteosyntese af suprakondylære humerusfrakturer hos børn Nord Med 66 1266-1268 1961

Acta orthop. Scandinav. XXXIV, 149–157, 1964

From the Orthopaedic Clinic, Sahlgrenska Sjukhuset, Gothenburg, Sweden (Head: Professor Carl Hirsch) and the Department of Surgery, University Hospital, Umeå, Sweden (Head: Professor Stig Borgström)

# OSTEOSYNTHESIS OF MEDIAL COLLUM FRACTURES WITH THE "SPRING-LOADED NAIL"

By

NILS RYDELL

A new method of osteosynthesis in fractures of the femoral neck has been developed in order to prevent nail slipping, to produce compression between fracture surfaces and to maintain better fracture healing. In an earlier work, "A new apparatus for the measurement of the compression between two bony surfaces and a construction for compression in fractures of the femoral neck" (Acta Orthopaedica Scandinavica, Vol. XXXI, Fasc. 1, 1961), the author has given an account of this method. For references the reader is referred to this article. The results of the first two years' experience are now given.

## NAIL SLIPPING

There is still much discussion going on regarding the technique of osteosynthesis in medial collum fractures and the causes of numerous complications are the object of various forms of analyses. Nail slipping is an usual complication of ostesynthesis of medial collum fractures. This can be due to a number of reasons. In most of the cases the nail slips because of resorption in the area of the fracture. Such a resorption leads to a shortening of the neck. When the nail lies sequestrated and surrounded by connective tissue membrane it soon loses its hold and slips out. By sinking the lower part of the nail's head under the cortical shell, theoretically the nail slipping should be made more difficult. This is what happens when a callus forms around the head of the nail, but this can hardly be expected within the first few months. Some authors warn against this technique, believing it will decrease the holding strength of the osteosynthesis. In order to determine to what

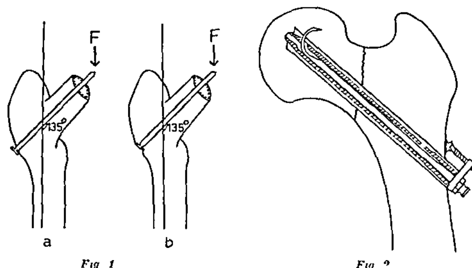



*Fig 1*  *Fig 2*

*Fig 1* Loading test a) the head of the nail outside the cortical shell b) the head of the nail sunk under the cortical shell
*Fig 2* The spring loaded nail in position

extent the efficiency of the osteosynthesis in neck fractures is influenced by sinking the head of the nail loading tests were performed on 20 autopsy specimens Bilateral autopsy specimens were used choosing right or left legs at random for the experiments The head was excised by a subcapital sawcut perpendicular to the long axis of the neck so that the length of the neck fragment was about the same in all specimens A Smith Petersen nail was then inserted into the femur at about 135 In ten cases the nail was driven in so far that the lower part of its head came to lie just inside the lateral cortex of the femur In the remaining ten cases it was inserted so that the head reached right to the outside of the lateral corticalis As the nails whose heads were sunk under the corticalis came to lie about half a centimetre longer medially these nails were chosen half a centimetre shorter In this way the same leverage was maintained during the loading tests The femoral specimens were then placed in an Amsler testing machine and the point of the nails loaded (Fig 1) Under fairly light loading the nails obtained a varus position in all cases and started to slip out In only one case was the load that started the moving of the nail over 75 kp the smallest force being 30 kp No difference between the two groups could be recorded either regarding the strength of the fixation or the tendency to slip out



*Fig 3*
X ray showing the nail in position

Nail slipping is prevented in many clinics by fastening the lateral part of the nail to the femur with a plate or a screw The disadvantage of this method is that resorption at the neck will either result in a diastasis between the fracture surfaces or the nail will penetrate into the joint

## PRESENTATION OF THE METHOD

With a view to preventing the nail slipping from the proximal fragment without the risk of diastasis at the fracture surfaces or penetration of the nail into the joint a new nail construction has been developed earlier presented in Acta Orthopaedica The principle of the construction is that a spring pin is inserted in a 4 flanged Smith Petersen nail and this pin is directed out in a bow at the side of the nail The nail is in this way securely fastened in the head Despite its small dimensions the pin resists a pulling force of 40–50 kp The nail has also been furnished with a plate the function of which is to produce compression between the fracture surfaces (Fig 2) The plate is not fixed to the femur s lateral surface in order to prevent a diastasis arising between the fracture surfaces during neck resorption Fig 3 shows X ray of a 78 years old patient with the nail in position

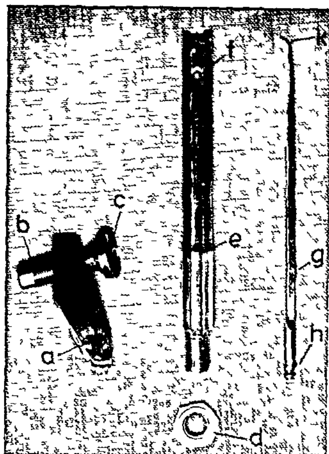



*Fig 4*

Instrument for osteosynthesis of fractures of the medial femoral neck
a = plate b = compression screw c = supporting plate against the trochanteric area
d = nut with nylon lock washer e = 4 flanged nail f = hole for spring pin
g = spring pin h = lock ring k = the curve of the pin

## MATERIAL

The material presented here is made up of twenty six dislocated medial collum fractures The cases were selected at random Only fractures with varus dislocation were included and each was closed reduced and nailed with this particular appliance Even patients in a very poor general condition were operated upon The average age of the subjects was 67 years Of these 19 were women with an average of 72 and 7 men with an average age of 52 7 of the 26 patients 6 women and one man died The average age of the dead was 74 years The cause

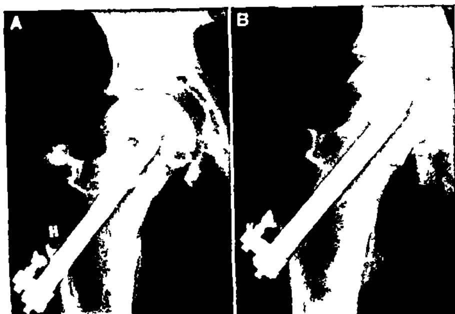



*Fig 5*
X-rays from a nailed hip fracture
a soon after the operation b some months later

of death in every case was cardio-vascular disease Only one of the patients died while still in hospital the other 6 at home before the follow up was finished The difference in the average age between the male and female patients is of interest Even if the material is small the tendency is clear and by examining the kind of accident it was shown that adequate force is the cause of fracture in the male clientele whilst in the female group falling on the floor or similar slight traumata had sufficed to produce the fracture

By measuring the distance arising between the surface of the screw (Fig 4c) and the surface of the femur's lateral cortex it was in all cases possible to measure the arising collum resorption with the subsequent shortening It was seen that in most cases a collum resorption with shortening arose at an early stage and then became constant Fig 5 shows X rays soon after operation (a) and some months later (b) Notice the gap between the screw and the bone in b The extent of shortening was found to be between 5 and 10 mm In two cases the collum resorption did not appear until one year after the operation one of these represents the only case of aseptic necrosis of the caput In

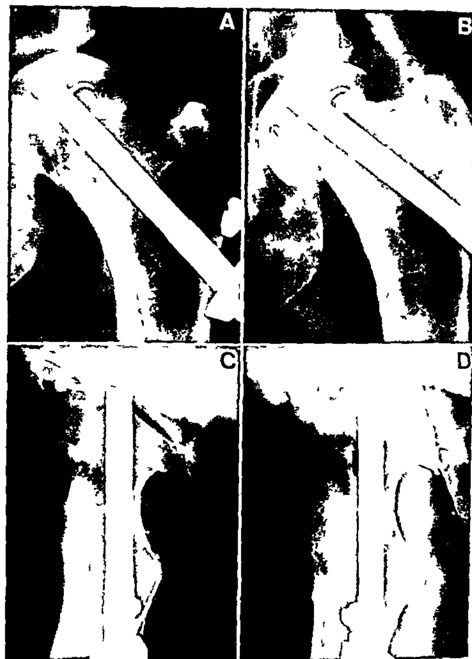



*Fig. 6*
X rays from the case with necrosis of the femoral head. A and C taken shortly after the operation, B and D one year later.

some cases during the healing process a slight varus position was met with but in no case did the tip of the nail loose its grip in the caput but remained all the time in an unchanged position in the caput fragment This was so even in the case of the necrosis where finally a small fragment of caput was left hanging on the tip of the nail (Fig 6)

## FINAL RESULT

All 19 surviving cases could be followed up of which 13 were women with an average age of 70 and six were men with an average age of 50 years

In one case a 55 years old woman caput necrosis developed The fracture was nailed after exact reduction Only some months later the patient complained of severe pain in the hip joint but no X ray evidence of necrosis could be seen until ten months had elapsed One month after the operation the patient walked very well and had almost normal hip movements After a further couple of months the movements were limited by pain and she was unable to walk more than a short distance Later on a Moore prosthesis was put in

In the remaining 18 cases healing progressed normally Partial weight bearing was allowed after six weeks and full weight bearing after ten weeks In no case was there any pain from the operated hip joint either at rest or after weight bearing The postoperative mobility of the hip joint was not less than before injury All patients were satisfied with the final result and were able to resume their previous activities

In all cases the nail remained in the caput in an unchanged position but due to the shortening in the collum the plate and the lateral part of the nail protruded into the soft parts more than immediately following the operation Many of the patients experienced some discomfort and tenderness over the lateral part of the nail In two cases a secretion arose from the wound although without any other effects on the patient All nails were removed after the fractures were healed The purpose was to see if there were any corrosion in different parts of the nail No corrosion was found

The compression applied to the fracture surfaces at the time of the operation could not be maintained more than a few months

## SUMMARY

A material consisting of twenty-six femoral neck fractures which were nailed with a new fixation device—a spring loaded nail is reported. 7 patients died and the 19 surviving patients were followed up. Two years was the shortest time between the operation and the follow up. In one case caput necrosis arose and in the other 18 cases the final result was satisfactory.

The device is so constructed that it primarily provides compression between the fracture surfaces and makes it impossible for the nail to slip out of the proximal caput fragment. Therefore the nail does not lose its hold in the caput and the contact in the fracture area is thus maintained. The result achieved up to now shows that the method offers certain advantages. Whether the fixation in the caput is of sole importance to the good results or whether the applied compression at the time of the operation is of value cannot so far be judged.



## RÉSUMÉ

Rapport sur un materiel d'observation comprenant vingt-six fractures du col fémoral clouées par une nouvelle forme de fixation le « clou avec charge à ressort ».

7 malades moururent. Les 19 malades survivants ont été suivis. Deux ans représentent la plus courte période d'observation depuis l'opération. Dans un cas il a été observé une nécrose de la tête et dans les autres 18 cas le résultat final fut satisfaisant.

Le clou est construit de manière à assurer primairement la sompression entre les surfaces de la fracture et empêcher le clou de sortir du fragment proximal de la tête. Le clou ne lâche donc pas sa prise dans la tête et le contact de la surface de la fracture est maintenu. Le résultat obtenu jusqu'ici montre que cette méthode offre certains avantages. On ne peut pas encore juger si la fixation dans la tête est le seul élément important par rapport aux bons résultats ou si la compression appliquée au moment de l'opération présente une valeur.



## ZUSAMMENFASSUNG

Über ein Material von sechsundzwanzig Schenkelhalsbrüchen, die mittels einer neuen Fixationsvorrichtung – einem mit einer Sprungfeder versehenen Nagel – behandelt wurden, wird berichtet. 7 Patienten starben und die 19 überlebenden Patienten wurden nachuntersucht.

Zwei Jahre ist die kurzeste Zeit zwischen der Operation und der Nach untersuchung In einem Falle entstand eine Kopfnekrose und in den anderen 18 Fallen war das Ergebnis zufriedenstellend

Die Vorrichtung ist so konstruiert dass sie unmittelbar eine Kom pression zwischen den Bruchoberflächen herstellt und das Heraus gleiten des Nagels aus dem proximalen Kopffragment unmoglich macht Daher verliert der Nagel seinen Griff am Kopfe nicht und der Kontakt in der Bruchregion bleibt auf diese Weise erhalten Die bisher erhalte nen Ergebnisse zeigen dass die Methode gewisse Vorteile darbietet Ob die Ruhigstellung im Caput allein fur die guten Resultate verantwort lich ist oder ob die anlasslich der Operation angewandte Kompression das Wertvolle ist kann zur Zeit nicht festgestellt werden

## REFERENCE

*Rydell Nils* A new apparatus for the measurement of the compression between two bony surfaces and a construction for compression in fractures of the femoral neck Acta orthop Scandinav *31* 1–17 1961

Acta orthop. Scandinav. XXXV, 158–163, 1964

From the Department of Surgery II, Sahlgrenska Sjukhuset, University of Gothenburg, Sweden (Head: Professor Ragnar Romanus, M.D.)

# WIRE TRACTION COMPLICATIONS ASSOCIATED WITH TREATMENT OF FEMORAL SHAFT FRACTURES

*By*

HANS DENCKER

The most common complications attendant upon wire traction are infection, cutting through and nerve lesions.

Attachment at the tibial tuberosity for skeletal traction of femoral shaft fractures is considered to be adequate by most surgeons. *Böhler* (1957) said: "The use of the pin or wire—and particularly of the clamp—above the knee joint may lead to severe complications. Empyema of the knee joint, infection of the hematoma in fractures close to the knee joint followed by osteomyelitis, ankylosis of the knee joint, amputation and death have been observed."

*Biebl's* series (1936) comprised 255 patients treated with wire traction for different fractures. The calcaneus, the distal part of the femur and the tibial tuberosity were the sites of application in 106, 46 and 23 cases respectively. In 2 osteitis supervened. One of the fractures had been treated with traction through the calcaneus and the other through the distal part of the femur. No nerve lesion was noted. In *Schildt's* investigation (1946), in which wire traction was applied 540 times for different fractures, the site of application was the distal part of the femur in 214 cases and the tibial tuberosity in 103. Altogether 52 wire traction complications were recorded: 30 cases of infection without cutting through of the wire, 18 of cutting through with or without infection and 4 of nerve lesion. All severe complications occurred in the cases in which supracondylar traction had been employed. *Aronsson* (1950) noted infection in 15 per cent of 129 patients with intertrochanteric or pertrochanteric fractures of the femur treated with wire traction. Osteomyelitis was the immediate cause of death in 1 case. The traction had been applied through the distal part of the femur.

In the opinion of *Watson Jones* (1955) the wire should not be ap-

plied through the distal part of the femur in skeletal traction owing to the risk of adhesions in the knee joint with resultant restriction in range of movement. The latter writer considered that the cause of adhesions is frequently low grade infection at the pin track.

Ligament damage may develop in the knee joint as a result of prolonged traction through the tibial tuberosity, i.e. for longer than about 6 weeks (*Bohler* 1957). On the other hand *Watson Jones* (1952) stated that if traction is not carried out with too heavy weights such damage will not occur.

## MATERIAL

The present investigation comprises 1 003 recent fractures of the femoral shaft in 992 patients. This is the total number of such fractures in patients 17 years old or more treated at practically all hospitals in Sweden during the three year period 1952 to 1954.

The different methods of treatment for closed and open fractures are listed in Table 1.

TABLE 1

*Survey of Different Methods of Treatment of Femoral Shaft Fractures at Swedish Hospitals During the Three Year Period 1952 to 1954*

| Method of treatment | Closed fractures | | Open fractures | | Total | |
|---|---|---|---|---|---|---|
| | no | | no | | no | |
| No treatment | 9 | 1 | 3 | 3 | 12 | 1 |
| Primary thigh amputation | 1 | 0.1 | 2 | 2 | 3 | 0.3 |
| Closed methods | | | | | | |
| Traction | [illegible] | 31 | 43 | [illegible] | 318 | [illegible] |
| Other | 10 | [illegible] | 1 | 1 | 11 | 1 |
| Open method | | | | | | |
| Intramedullary nailing | [illegible] | 44 | 43 | 37 | 43 | 43 |
| Encircling wire | 100 | 11 | 4 | 4 | 104 | 10 |
| Plate and screw | [illegible] | 5 | 8 | 7 | 54 | |
| Others | 50 | 6 | 9 | 8 | 59 | 6 |
| Transfixation | 4 | 1 | 3 | 3 | [illegible] | 1 |
| Total | [illegible] | 100 | 116 | 100 | 1 003 | 100 |

Wire was chosen for traction in almost every fracture treated in that manner. The site of its application occasionally varied but not according to any definite plan. In some instances the reason was stated to be complications.

TABLE 2

*Wire Traction Complications During Hospitalization*

| Duration of traction | Tibial traction no | Type of complication | | | | | | Femoral traction no | Type of complication | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cutting through no | Soft tissue inf no | Bone inf no | Nerve lesion no | Total no | Total / | | Cutting through no | Soft tissue inf no | Bone inf no | Nerve lesion no | Total no | Total / |
| ≦2 weeks | 279 | 1 | 2 | – | 1 | 4 | 1 | 128 | 4 | 1 | – | – | 5 | 4 |
| >2 4 weeks | 118 | 3 | 1 | 1 | – | 5 | 4 | 39 | 2 | 4 | 1 | – | 7 | 18 |
| >1 2 months | 147 | 4 | 3 | – | – | 7 | 5 | 59 | 1 | 4 | 1 | 1 | 7 | 12 |
| >2 3 months | 88 | 2 | – | – | – | 2 | 2 | 41 | 2 | 3 | – | – | 5 | 12 |
| >3-4 months | 41 | 1 | 3 | – | – | 4 | 10 | 19 | 1 | – | – | – | 1 | 5 |
| >4 months | 11 | – | – | – | – | – | – | 6 | – | – | – | – | – | – |
| Total | 684 | 11 | 9 | 1 | 1 | 22 | 3 | 292 | 10 | 12 | 2 | 1 | 25 | 9 |

I yarthrosis + ankylosis

This table excludes 1 complication (bone infection) which resulted from traction though the calcaneus The traction was applied for 2 months

Skeletal traction was used as definitive therapy for 316 fractures. In these wire traction was applied altogether 401 times—through the tibial tuberosity in 261 cases, through the distal part of the femur in 129, and through the calcaneus in 11.

Wire traction was employed before and after open reduction 604 times—through the tibial tuberosity in 423 cases, through the distal part of the femur in 163, and through the calcaneus in 18.

Infection, cutting through, and nerve lesion were the wire traction complications recorded during hospitalization. Complications occurred in 3 per cent when the wire was applied through the tibial tuberosity and in 9 per cent through the distal part of the femur (Table 2). The difference is statistically significant ($\chi^2 = 12.76$ with d.f. = 1).

TABLE 3

*Knee-Joint Flexion in Fractures treated with Traction Distributed According to the Site of Application. In these Cases the Mobility of the Joint was Normal Prior to Fracture and Probably Unaffected by Multiple Injuries*

| Duration of traction | Tibial traction alone | | Femoral traction alone | | Both tibial and femoral traction | |
|---|---|---|---|---|---|---|
| | 90° or more | Less than 90° no. | 90° or more no. | Less than 90° no. | 90° or more no. | Less than 90° no. |
| ≦1 month | 3 | – | – | 1 | 1 | – |
| >1–2 months | 23 | 1 | 21 | – | 4 | 1 |
| >2–3 months | 3[illegible] | | 18 | | 5 | – |
| >3 month | 24 | 5 | 11 | 1 | 9 | 2 |

Table 3 presents the mobility of the knee joint at my follow-up examination of fracture cases treated with traction. No significant difference was found between traction through the tibial tuberosity and the distal part of the femur. Infection was observed at the attachment of the wire in 3 of 11 cases where flexion was less than 90 degrees—in 2 associated with femoral and in 1 with tibial traction.

Follow-up examination revealed that knee joint instability which might have been connected with the fracture treatment was present in only 3 of 702 cases. Two of these fractures had been nailed (lateral instability of 15 to 20° of the extended joint in both) and one treated with traction (10° lateral instability of the extended joint). In the latter case the traction had been applied through the tibial tuberosity for 3½ months. The healing course was complicated in all 3 cases—by bone infection in 2 and by refracture in 1.

## DISCUSSION

The incidence of wire traction complications during hospitalization was low, 5 per cent of 1 005 applications. This might be due to the fact that less severe complications were not noted in the case records and had been forgotten by the patients when they were interviewed on follow up. Traction through the distal part of the femur led to more numerous and severe early complications than when it was applied through the tibial tuberosity—an observation which agrees with the views expressed by other authors.

Instability of the knee joint was not more frequent following tibial traction than after other methods of treatment. The large number of cases which form the basis for the observation lend strong support to the conclusion that traction through the tibial tuberosity does not give rise to such damage. This site of application had been employed for more than one month in 134 fractures in the follow up series (for one to two months in 51 cases, for two to three months in 46, and for more than three months in 37). In only 1 case is there any possible relation of instability for the tibial application site. The treatment had been applied for 3½ months with adequate weights, suggesting that excessive traction was not the underlying cause.

## SUMMARY

The present investigation is a study of wire traction complications of treatment for fractures of the femoral shaft applied at Swedish hospitals during the three year period 1952 to 1954—altogether 1 005 applications. Wire traction complications during hospitalization developed less often and were less severe when the site of attachment was the tibial tuberosity instead of the distal part of the femur. The frequency of complications was 3 per cent for the former site of application and 9 per cent for the latter. In no instance could it be evidenced with certainty that traction through the tibial tuberosity led to instability in the knee joint. Consequently, the latter site of attachment should be selected.

## RÉSUMÉ

La présente enquête porte sur l'étude des complications consécutives à la traction par fil dans le traitement des fractures du corps fémoral appliqué par les hôpitaux suédois durant la période de trois ans 1952 à 1954 comprenant en tout 1005 cas. Les complications de la traction

par fil durant l hospitalisation ont ete moins frequentes et moins graves lorsque l endroit de l attache etait le condyle tibial au lieu de la partie distale du femur La frequence des complications a ete de 3 pour cent pour les premiers et de 9 pour cent pour les derniers Dans aucun cas *il n a ete prouve la traction a travers le condyle* tibial entrainait l instabilite de l articulation du genou Il convient par consequent de selectionner la partie distale du femur comme endroit d attache

## ZUSAMMENFASSUNG

Die vorliegende Untersuchung befasst sich mit den Komplikationen der Drahtstreckbehandlung von Oberschenkelschaftbruchen die wahrend der Dreijahrsperiode 1952 bis 1954 insgesamt 1005 mal verwendet wurde Drahtstreckkomplikationen wahrend des Aufenthaltes im Krankenhause entwickelten sich seltener und waren weniger schwer wenn die Extension an der tuberositas tibiæ anstatt am distalen Ende des Femurs angebracht wurde Die Haufigkeit von Komplikationen war 3 Prozent fur die ersterwahnte Methode und 9 Prozent fur letztere In keinem Falle konnte mit Sicherheit nachgewiesen werden dass Zug an der tuberositas tibiæ zu einer Instabilitet des Kniegelenkes fuhrte Es sollte daher dieser Sitz für die Streckbehandlung gewahlt werden

## REFERENCES


*Aronsson H* The Treatment of Intertrochanteric and Pertrochanteric Fractures of the Femur Traction Treatment or Internal Fixation? Acta chir Scandinav *100* 110 1950

*Biebl M* Fruh und Spatkomplikationen bei der Drahtextension Zbl Chir *63* 2080 1936

*Bohler L* The Treatment of Fractures Volume III Fifth edition in English (based on the 12–13th German edition) Grune & Stratton New York and London 1957

*Dencker H M* Fractures of the Shaft of the Femur A Clinical Study Based on 1 003 Fractures Treated in Swedish Hospital During the Three Year Period 19 ? to 1954 Orstadius boktryckeriaktiebolag Goteborg 1963

*Schiller F* Komplikationer vid trådstracksbehandling Nord Med *29* 301 1946

*Watson-Jones R* Fractures and Joint Injuries Fourth edition Volume I and II E & S Livingstone Ltd Edinburgh and London 1952 1955

Acta orthop. Scandinav. XXXIV, 164–169, 1964

From the Department of Surgery II, Sahlgrenska Sjukhuset, University of Gothenburg, Sweden (Head: Professor Ragnar Romanus, M.D.)

# ERRORS IN TECHNIQUE AND COMPLICATIONS SPECIFIC TO INTRAMEDULLARY NAILING

*A Study Based on 459 Nailed Femoral Shaft Fractures*

*By*

HANS DENCKER

Special errors in technique and complications can occur at intramedullary nailing of femoral shaft fractures. These have been considered closely by *Böhler* (1948), *Lauritzen* (1949) and *Palmer* (1951).

Among the more common errors in technique are the use of too short or too thin a nail, impaction, nail perforation of the proximal or distal fragment or into the knee joint, splitting of the femur, and nailing with a gap between the fracture ends. Bending and breaking of the nail are the most important complications specific to the method.

These errors in technique and complications vary appreciably in incidence in different series. In *Lauritzen's* material (1949), technical difficulties of an unpleasant nature were encountered only when the calibre selected was incorrect, i.e. when the nail was too thick, but their frequency was not specified. The nail bent in 7 of 46 cases. *Folles* (1951) reported 11 technical errors among 51 nailing operations. In 4 instances the nail bent and in 1 it broke. In *Key & Folles'* series (1951) breaking of the nail occurred in 9 of 684 femoral fractures.

## MATERIAL

The present series of femoral shaft fractures is collected from practically all Swedish hospitals during 1952–1954. The designation femoral shaft fracture denotes here a fracture situated in its entirety on the shaft itself. The upper limit on the shaft is taken at 5 cm below the distal margin of the lesser trochanter and the lower at 6 cm proximal to the most distal point of the medial femoral condyle, as measured on available roentgen films (see *Dencker* 1963).

Intramedullary nailing was performed in 435 fractures. The method was given a trial in a further 24 cases but failed owing to technical errors and another method was used. For this reason the percentage of technical errors is estimated on the basis of 459 cases, while the percentage of postoperative complications is calculated for 435.

## TECHNICAL ERRORS AT NAILING OPERATIONS

Technical errors which have been rated as sufficiently important to be noted were in 63 cases (14 per cent) recorded in the surgeons' reports or discovered on reexamination of the roentgen films.

*The use of too short a nail* was the most common technical error occurring at 25 operations. In about one third of the cases this was due to the lack of a suitable nail during the operation. The causes are not known in the remaining instances.

In fractures of the upper and middle thirds of the femoral shaft the nail was considered too short if it failed to reach at least 10 cm beyond the fracture. When a fracture implicated the lower third of the shaft the length of the nail was thought to be inadequate if it did not reach to within approximately 4 cm of the most distal point of the medial femoral condyle. These definitions are selected as in one third of the above 25 cases displacement occurred postoperatively, most probably because the nail was too short. In the cases in which a longer nail was used postoperative fracture displacement was probably due to other factors.

*Impaction* of the intramedullary nail was recorded at 24 operations. The surgeon succeeded with difficulty in withdrawing the nail in 12 cases, but he failed in 12. In 11 of the latter cases the nail was sawn off, and in 1 its projecting end was buried under the skin at the greater trochanter.

In 4 of the 12 cases in which it was possible to withdraw the nail a new one of smaller calibre was employed. Three of the fractures were instead treated with a plate, 2 with bone suture, and 2 with open reduction without internal fixation. In 1 the guide pin was left in position to fix the fracture.

Open reduction without internal fixation was employed in 5 of the 12 cases in which the nail could not be extracted. Encircling wire was used in 3 fractures, an intramedullary pin in 1, and bone suture in 1. In 2 the guide pin was left to fix the fractures.

*Splitting of the femur* occurred at 6 nailing operations. As a rule a bone fragment was dislodged measuring around 3 cm in frontal and lateral projections on the roentgen films. This complication was in every instance probably due to the use of a nail of too large a calibre.

The nailing operation was completed in 5 of the latter 6 cases but the fixation was not stable and external fixation was therefore applied One of the fractures was instead treated with bone suture

*Nail perforation into the knee joint*—approximately 0 5 cm into the intercondylar fossa—was noted in 3 cases This was due to inaccurate estimation of the lenght of the femur

*The surgeon failed completely to drive the nail into the medullary cavity in 3 cases* Two of the fractures were instead treated with encircling wire and 1 with bone suture

*The nail was driven out into the soft tissues* around the fracture in 2 cases In neither instance was the error detected at the operation as no roentgen check was made Both fractures were reoperated upon shortly after with a new intramedullary nail

## COMPLICATIONS SPECIFIC TO INTRAMEDULLARY NAILING

Bending and breaking of the nail were the complications specific to intramedullary nailing of the greatest significance The incidence of bursa formation at the proximal end of the nail cannot be ascertained This complication was not usually recorded at extraction of the nail and roentgen examination of the hip was seldom made at that time

*The nail bent* in 68 cases (16 per cent) The degree of bending as measured on the roentgen films and therefore representing a minimum value was in 43 cases less than 15 in 19 between 15 and 25 and in 6 over 25

The bending of the nail occurred within the first month in 22 cases during the second to fourth months in 26 and later after the operation in 20

In 3 cases the nail was bent between 5 and 10 at application but was left in position. In 9 the bending occurred when the patients were confined to bed The nail bent on loading the limb in 48 cases and in 8 by trauma at an accident

*The nail broke* in 10 cases (2 per cent)

## DISCUSSION

Technical errors at intramedullary nailing were recorded in 14 per cent of the 459 cases If it is borne in mind that the operations in this series were performed by a large number of different surgeons the in

cidence is not particularly high *Palmer* (1951) for instance who is much interested in intramedullary nailing reported 7 technical errors among 52 such operations for femoral fractures However it seems likely that more occurred in the present series It may well be that all of them were not noted in the surgeons reports or detected on reexamination of the roentgen films

The most common error was the use of too short a nail This was often due to the lack of a suitable one which suggests that the planning of the operation had been imperfect If the control of the available internal fixation material had been better the erroneous procedure might have been avoided The intramedullary nailing operation could not be completed in 24 cases (5 per cent) and other methods had to be employed instead The cause was usually impaction

Several writers have emphasized the need of the experience and skill for good results at intramedullary nailing (*Bohler* 1948 *Luck* 1951 *Smith* 1951 *Key* 1955 among others) Thus a comparison has been made here of the surgeons length of training and the incidence of technical errors but this revealed no significant difference (Table) The

TABLE

*Incidence of Technical Error at Nailing Operations in Relation to the Surgeon s Training*

| Length of training | No of operation | Technical error no |
|---|---|---|
| <2 year | 16 | 0 |
| 2 5 years | 92 | 12 |
| >5 years | 313 | 49 |
| Unknown | 14 | 2 |

fact that no errors were attributed to surgeons with less than 2 years training was probably due to their calling in a more experienced surgeon when they got into difficulties and that the operation was then recorded in the latter s name

Bending of the nail was the most common postoperative complication specific to intramedullary nailing occurring in 68 instances (16 per cent) *In two thirds of the cases the bend was less than 15 degrees* Nails V shaped in cross section were generally employed in the present series Nowadays however clover leaf nails are in wide use (*e g Palmer* 1957 *Kuntscher* 1958) which should lead to a fall in the incidence of

bending. The complication usually occurred within 4 months of the operation. It seems that it might have been prevented in several cases if the limb had not been exposed to weight bearing until somewhat later.

The nail broke in 10 cases (2 per cent). Most authors believe a break to be the result of metal fatigue or trauma (*Fischer, Wasels & Schunemann* 1953, *Lottes & Key* 1953). In the present investigation metal fatigue was probably the cause of the break in 9 cases and trauma in 1. The case records contained no mention of signs of corrosion of the nail so this factor was probably of no importance.

## SUMMARY

Errors in technique at intramedullary nailing operations were observed in 14 per cent of the 459 cases which were treated at Swedish hospitals between 1952 and 1954. The nail bent in 16 per cent and broke in 2 per cent. The causes and possible preventive measures are discussed.

## RESUME

Des defauts techniques dans les operations d'enclouage intramedullaire ont été observes dans 14 pour cent des 459 cas traites dans les hopitaux suédois entre 1952 et 1954. Le clou s'est courbé dans 16 pour cent et s'est casse dans 2 pour cent des cas. Il est discuté des causes de ces accidents et de dispositions preventives qu'il est possible de prendre.

## ZUSAMMENFASSUNG

Fehler bei der intramedullären Nagelung wurden in 14 Prozent der 459 Falle, die in schwedischen Krankenhäusern zwischen 1952 und 1954 behandelt wurden, beobachtet. Der Nagel beugte sich in 16 Prozent und brach in 2 Prozent. Die Ursachen und moglichen vorbeugenden Massnahmen werden besprochen.

## REFERENCES

*Böhler L.* Medullary Nailing of Küntscher. The William & Wilkins Co. Baltimore 1948.

*Dencker H. M.* Fractures of the Shaft of the Femur. A Clinical Study Based on 1003 Fractures Treated in Swedish Hospitals During the Three Year Period 1952 to 1954. Orstadius boktryckeriaktiebolag, Göteborg 1963.

*Fischer Wasels J & Schunemann H B* Zur Frage der Marknagelfrakturen Arch orthop Unfall Chir 46 207 1953/1954

*Key J A* Indications on Contraindications for Medullary Nailing of Fractures J A M A 158 1001 1955

*Key J A & Lottes J O* Medullary Fixation of the Femur Complications and Errors in Technique Am Acad Orthopaedic Surgeons Instructional Course Lectures 8 97 1951

*Kuntscher G* The Kuntscher Method of Intramedullary Fixation J Bone Jt Surg 40-A 17 1958

*Lauritzen G K* Medullary Nailing A Clinical and Critical Study Acta chir Scandinav Suppl 147 1949

*Lottes J O* Treatment of Fractures of the Femur with a Heavy Large Cored Three Flanged Medullary Nail Surgery 29 868 1951

*Lottes J O & Key J A* Complications and Errors in Technic in Medullary Nailing for Fractures of the Femur Clin Orthop 2 38 1953

*Luck J V* Medullary Fixation of the Femur Advantages Limitations and Indications Am Acad Orthopaedic Surgeons Instructional Course Lectures 8 ? 1951

*Palmer I* On the Complications and Technical Problems of Medullary Nailing Acta chir Scandinav 101 484 1951

*Palmer I* Marg pikning vid femurfrakturer Granskning av ett material vid Soder sjukhusets kirurgiska klinik I Nord Med 57 101 1957

*Smith H* Medullary Fixation of the Femur Am Acad Orthopaedic Surgeons Instructional Course Lectures 8 1 1951



Acta orthop. Scandinav. XXXV 171–184 1965

# A QUANTITATIVE HISTOLOGICAL STUDY OF RIB FROM 18 PATIENTS TREATED WITH ADRENAL CORTICAL STEROIDS[1]

*By*

M. Klein, A. R. Villanueva[3] and H. M. Frost[4]

## INTRODUCTION

Many investigators have followed the lead of *Bauer, Carlsson & Lindquist* (1) in developing and applying *in vivo* tracer methods for the study of bone physiology and disease. These methods have proven powerful and valuable and within their province yield information not available by other existing methods.

One of the early hopes in using these methods was that they could yield direct information about the kinetics of the cells ultimately responsible for most features of bone physiology and pathophysiology. This hope has not yet materialized. It became clear, at least to some, that interpretation of skeletal tracer based studies in terms of cell kinetics must await better knowledge of these cells obtained with other techniques, and subsequent correlation of this knowledge with tracer studies.

This impasse was broken by two major developments on the cell front. One was the discovery and use of *in vivo* tetracycline labelling of newly forming bone as a research tool, initiated by the reports of *Milch, Rall & Tobie* in 1957 and 1958 (13, 14). This provided bone histologists with a marker in time and a reliable label of foci of new bone formation. The second was the use of autoradiography and tritium labelled thymidine to study the physiology of new cell generation in a wide range of

---

[1] Grants [illegible]93 NIH AM 04186.

Research Fellow, Orthopaedic Research Lab., Henry Ford Hospital.

[3] B.S., Research Associate, Orthopaedic Research Lab., Henry Ford Hospital.

[4] Associate Orthopaedic Surgeon, Division of Orthopaedic Surgery, Henry Ford Hospital.

tissues and organisms including bone. This was started by the reports of *Belanger & LeBlond* (2) and has been followed up by many, among them *Quastler* (16), *Kember* (12), *Young* (22, 23) and *Owen* (15).

These developments afforded histologists an unparalleled chance to study dynamic bone cell phenomena. A considerable body of knowledge provided by work based on these methods now exists, and it is time to begin studying disease in the light of this knowledge.

In this report studies are reported of bone obtained from 18 patients treated with adrenal cortical hormones or their synthetic homologs.

The system we have studied is internal remodelling of lamellar bone. The methods used are quantitative histological.

A summary of some relevant cell dynamics in bone remodelling will help to understand our data.

## RELEVANT SUMMARY OF BONE REMODELLING

Bone is made by cells called osteoblasts, and destroyed or resorbed by others called osteoclasts (*Ham & Leeson* (10)). Neither osteoclast nor osteoblast can reproduce itself. Both are generated by cell division from a primitive cell called the osteoprogenitor cell by *Young* and the *mesenchymal cell* by us (*Young* (22) 1962, (23) 1963 and *Frost* (6) 1963). Mesenchymal cells apparently cannot resorb or make bone themselves and must somehow be instructed from their environment to begin making daughter cells. Once so instructed, they are said to be *activated*, and a remodelling *focus* then occurs in the region where the activation happened.

Counts of such foci are thus a way of studying the location and frequency of activation. Each remodelling focus involves a finite amount of bone resorbed and made, each with some mean size and speed of evolution. A measure of size is surface area, because in resorption surface is being shaved off at so many microns per day, while in formation it is being added to.

A measure of evolution speed is the depth that is removed from, or added to, the surface per time unit.

The sizes and evolution speeds of remodelling foci are determined directly by osteoclasts and osteoblasts, and indirectly by agents and situations that regulate them.

It follows that changes in sizes and evolution speeds indicate changes in the activity of osteoclasts and osteoblasts, but do not have meaning in terms of the presence or lack of activation of mesenchymal cells.

*Therefore one can measure separately indices of both mesenchymal cell activation and of the activities of osteoclasts and osteoblasts*

## THE GEOMETRY OF INTERNAL REMODELLING OF LAMELLAR BONE

Three geometric properties of lamellar bone remodelling processes are very useful in relating anatomy to cell dynamics (6) These are

There is a mean yearly depth at which bone is shaved off or added to the surfaces of active remodelling foci Express this in millimeters per year and use the symbols ($M_r$ $M_f$) to designate it the subscripts identifying resorption or formation These have dimensions of length and time This can be measured in tetracycline labelled bone

There is a mean size of the resorption and formation foci Express this as the surface area to which active resorption or formation is limited It is given in square millimeters and designated by ($S_r$ $S_f$) These have dimensions of length squared This can be directly measured in mineralized sections

There is some mean number of foci during the year at which remodelling activity occurs one for resorption another for formation Designate these by ($A_r$ $A_f$) and express them in numbers per cubic millimeter These counts are easily done on mineralized sections

All of the bone resorption and formation that occours in a bone or skeleton can be calculated from the above measurements if they can be obtained This calculation involves the solution of two simple algebraic equations *viz*

$$V_r = k\ A_r\ S_r\ M_r \qquad (1)$$

$$V_f = k\ A_f\ S_f\ M_f \qquad (2)$$

In these equations ($V$) is the volume of bone resorbed or formed per year according to the subscript and ($k$) is the number of mm³ originally present For a one-year span of time with ($k$) equal to unity their solutions are the yearly bone resorption and formation rates respectively They are rates because they have dimensions of time and length cubed

## MATERIALS

The materials consist of the 5th 6th or [illegible]th rib of two groups of patients

1) The first group of 31 people had no known metabolic bone disease hormonal therapy [illegible] metastatic malignancy chronic illness congestive heart failure chronic infection diabetes mellitus or cirrhosis Three-quarters of these ribs were

obtained at thoracotomy for indications such as hiatus hernia cardiospasm biopsy of undiagnosed solid parenchymal lesions repair of patent ductus or aortic coarcta tion or repair of acute thoracic trauma The rest were obtained at autopsy causes of death including sudden vascular incidents homicide suicide and trauma It is believed that this group of ribs provides a representative sample of normal human bone Ages of these patients were from 51 to 60 years with a mean age of 57 for the group

2) The second group of 18 patients received an adrenal corticoid hormone or synthetic homolog in pharmacodynamic doses for more than two months before skeletal sampling Seven received these agents for a year or more

There were a variety of reasons for giving the corticoids ranging from lymphatic leukemia rheumatoid arthritis and pulmonary fibrosis to metastatic malignancy and thrombocytopenia Pertinent clinical data on these patients is given in Table 1 All of these skeletons were sampled at autopsy None of these patients received any other hormone during the time of corticoid therapy Only one (case 12) was clinical ly Cushingoid at the time of death

3) In addition to the above material there are in the laboratory s files over 200 normal bones other than ribs and over 50 bones other than ribs from corticoid treated patients These have been examined by the same techniques as those referred to next The changes in the corticoid bones are qualitatively similar to those in the ribs and add considerable weight to the significance of the 18 cases reported in detail This study is restricted to ribs because only this bone is present in normals in sufficient quantity to provide a valid norm for age based on measurement

## METHODS

1) Fresh hydrated mineralized cross sections of the ribs were made and stained with basic fuchsin by special methods (4 5) Completed sections were about 50 microns thick There were an average of more than three cross sections per case The sections were oriented within 5 degrees of perpendicularity to the longitudinal axis

2) The total cross section area is that enveloped by the periosteum as seen on cross section The cortical area is the total area minus the marrow area All three of these areas were measured using a modification of *Chalkley* s method (3 18) Accuracy was 1 0 mm precision 0 3 mm The cortical area was tabulated both as a total for the three sections and as the mean per section for later calculations

3) The total numbers of active osteoid seams (21) and of resorption foci (18) were then counted in the sections as described by *Sedlin et al* and *Villanueva et al* The means per mm of cortex were obtained by dividing the total numbers of foci by the cortical area of all sections of a case Because of the geometric properties of the sections and of the bones examined and of lamellar bone studied in cross sec tion and because of the design of the measuring method active seams/mm is equivalent to actice seams/mm$^3$ (18 21) In establishing this equivalence it is as sumed that one always refers to cross sections exactly one millimeter thick All numerical data in this work has this dimensional basis

4) The circumferences of the average active osteoid seam and resorption space were measured using a modification of *Chalkley Cornfield* and *Irk* s method (3 18) Zeiss integrating eyepieces and methods of calculation outlined elsewhere

TABLE 1

*Corticoid Patients*

The 18 cases in this study are listed with their age sex and major medical diagnosis at the time of post mortem Only one case was obtained at surgery (for lung biopsy #12)

| Case | HFH no | Sex | Age Yrs | Mths cort coid therapy | Pertinent diagnoses |
|---|---|---|---|---|---|
| 1 | 91 02 59 | M | 5 | 12 | Acute lymphatic leukemia |
| 2 | 53 93 27 | M | 11 | 18 | Acute lymphatic leukemia |
| 3 | 98 40 23 | M | 15 | 2 | Regional enteritis peritonitis thrombocytopenia |
| 4 | 85 59 29 | F | 15 | 24 | Rheumatoid arthritis pulmonary fibrosis |
| 5 | 102 50 51 | F | 15 | 4 | Metastatic sarcoma obscure bleeding diathesis |
| 6 | 94 17 73 | M | 34 | 4 | Metastatic Ca – lung |
| 7 | 98 95 12 | M | 46 | 2 | Metastatic Ca – lung |
| 8 | 102 90 86 | M | 50 | 4 | Uremia |
| 9 | 96 56 68 | F | 54 | 4 | Leiomyosarcoma Pancreas |
| *10* | *80 87 41* | *F* | *56* | *13* | *Metastatic Ca – colon* |
| 11 | 94 72 50 | M | 57 | 5 | Duodenal Ulcer pulmonary fibrosis emphysema gastrectomy |
| 12 | 98 26 66 | M | 58 | 48 | Ca – lung rheumatoid arthritis osteoporosis |
| 13 | 82 95 54 | F | 60 | 3 | Metastatic Ca Rectum congestive heart failure |
| 14 | 06 32 98 | M | 60 | 5 | Chronic lymphatic leukemia |
| 15 | 56 2 44 | F | 66 | 12 | Leukemia subdural hematoma Ca – tonsil |
| 16 | 62 4 14 | F | 68 | 18 | Metastatic Ca – breast |
| 17 | 16 20 92 | F | 68 | 4 | Cirrhosis liver diabetes mellitus |
| 18 | 96 97 60 | F | 68 | 5 | Rheumatoid arthritis Metastatic Ca |

Mean Age Cases 6—18 57 years

These measurements are reported as mm per formation or resorption focus and are calculated on the basis that the value obtains in cross sections one millimeter thick.

5) The rate at which new osteoid is added to the surface of an active osteoid seam may be measured by observing the rate at which *the zone of demarcation* converts osteoid to bone as it sweeps over new previously unmineralized bone matrix The motion of the zone of demarcation is labelled by the tetracycline anti

TABLE 2

*The Measurements of Each Steroid Treated Case are Listed*

| Column 1 Case | 2 $V_f$ # mm | 3 $A_r$ # mm | 4 $S_f$ mm² mm³ | 5 $S_r$ mm mm | 6 $M_f$ mm year | 7 $V_f$ $A_f$ | 8 Total cortical cross section area mm | 9 Ratio cortical to total area | 10 Sections | 11 Cortical area mm² per section |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 38 | | 603 | (0 20 ) | >100 | 13 0 | 45 | 1 | 13 |
| 2 | 0 | 50 | | 979 | (0 20 ) | >100 | 32 5 | 40 | 2 | 16 2 |
| 3 | 1 80 | 83 | 51 | 639 | (0 20 ) | 54 | 22 7 | 49 | 1 | 22 7 |
| 4 | 32 | 38 | 60 | 725 | (0 20a) | 1 0 | 110 3 | 51 | 3 | 36 6 |
| 5 | 0 | 81 | | 799 | (0 20a) | >100 | 39 4 | 56 | 2 | 19 7 |
| 6 | 075 | 1 10 | 38 | 464 | (0 20a) | 14 7 | 39 9 | 36 | 2 | 19 95 |
| 7 | 34 | 1 65 | 40 | 492 | (0 20a) | 3 7 | 64 0 | 23 | 4 | 16 |
| 8 | 0 | 664 | | 554 | (0 20a) | >100 | 55 7 | 24 | 3 | 18 5 |
| 9 | 0 | 90 | | 444 | (0 20a) | >100 | 30 5 | 28 | 2 | 15 25 |
| 10 | 0 | 1 14 | | 538 | (0 20a) | >100 | 22 7 | 23 | 2 | 11 35 |
| 11 | 061 | 23 | 53 | 343 | (0 20a) | 3 5 | 146 8 | 24 | 7 | 20 97 |
| 12 | 027 | 29 | 306 | 699 | (0 20 ) | 15 2 | 36 7 | 29 | 2 | 18 35 |
| 13 | 17 | 13 | 35 | 212 | (0 20 ) | 1 0 | 29 8 | 34 | 3 | 9 93 |
| 14 | 0 | 58 | | 479 | (0 20a) | >100 | 18 7 | 33 | 2 | 9 35 |
| 15 | 0 | 1 0 | | 499 | (0 20a) | >100 | 36 0 | 28 | 2 7 | 13 1 |
| 16 | 068 | 94 | 244 | 90 | (0 20 ) | 18 8 | 14 8 | 41 | 1 | 14 00 |
| 17 | 0 | 46 | | 241 | (0 20a) | >100 | 30 5 | 23 | 3 | 10 17 |
| 18 | 0 | 66 | | 527 | (0 20 ) | >100 | 43 8 | 33 | 3 | 14 6 |

TABLE 3

*The Means and Ns are Compared for the Normal and Steroid Treated Patients*

| | $N_f$ all cases | $N_f$ cases 6-18 | $N_r$ all cases | $N_r$ cases 6-18 | $S_f$ all cases | $S_f$ cases 6-18 | $M_f$ | $S_r$ all cases | $S_r$ cases 6-18 | All cortical area (C.A.) | Adult cortical area | Ar $N_f$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Corticoids* | | | | | | | | | | | | |
| Arithmetic Mean | 159 | 059 | 471 | 759 | 419 | | 20 | 562 | 489 | 10.7 | 14.8 | 100 |
| Standard Deviation | 42 | 03 | 41 | 43 | 121 | | | 20 | 17 | 6.35 | 4.04 | |
| Standard Error | 09 | 03 | 09 | 01 | 046 | | | 054 | 048 | 1.5 | 1.12 | |
| N | 18 | 13 | 18 | 13 | 8 | | 6 | 18 | 13 | 18 | 13 | 18 |
| *Normals* | | | | | | | | | | | | |
| Arithmetic Mean | 380 | | 53 | | 53 | | | 405 | | | 11.0 | 1.4 |
| Standard Deviation | 6 | | 24 | | 056 | | | 13 | | | 5.9 | |
| Standard Error | 047 | | 045 | | 01 | | | 02 | | | 1.06 | |
| N | 31 | | 31 | | 31 | | 8 | 31 | | | 31 | 31 |

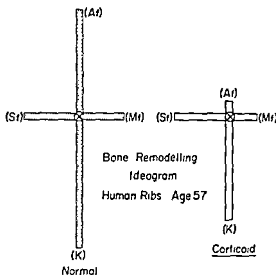



*Fig 1*

In this ideogram several of the measured parameters of bone remodelling are plotted These are from the formation equation (2) Normal values for age 57 are on the left while the values for the corticoid group in the present report are on the right The numerical values are taken from Table 3 —The bars on each side are homologous with each other and are identified in terms of the parameters in equation (1) text Note the marked decrease in numbers of sites of formation The bottom bars marked (k) represent the amount of bone in mm³ that would be present on the average cro s section The mm³ of bone is in absolute bone volume terms (5) meaning this is the amount of bone remaining after subtracting all of the normal porosities The porosities are the lacunae canaliculae Haversian and Volkmann s canals primary longitudinal canals and the marrow space

biotics when these agents are given for infections (7) About 45 per cent of the general hospital population contains one or more tetracycline labels according to Sedlin

6) It has been observed that in a standard bone the ratio of the corti al area to the total area is a useful index of the degree of osteoporosis (19) Accor lingly this ratio was calculated for both groups and is shown in column 9 Table ?

The normals for age 57 which is the mean age for the corticoid group have been determined by the means referred to While there are 31 patients in the normal group whose ages lie between 52 and 6? years the weight assignable to this group is augmented by the values of the groups on either side of it The likelihood that the numerical values of the normal group based only on the 31 patients in that group are in error due to chance is considerably less than 0 02 ($p < 0$ )

The corticoid treated patients are listed in Table 1 with pertinent information about their age sex and major medical diagno es The number of m nths each received the corticoids is also noted All received the corteoids continu usly during the interval indicated

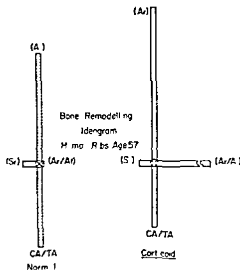



*Fig 2*

In this ideogram the parameters of the resorption equation (1) are diagrammed Note the significant increase in the numbers of sites of resorption ($A_r$) we feel this is due to accumulation which in turn is due to failure to initiate the formation of new bone in resorption spaces at a normal rate—Note the increase in the ratio of ($A/A_f$) in the corticoids This indicates that resorption spaces exist in corticoid treated bones much longer than normal before being filled in by new bone formation Since the bone formation process is probably also slowed down (see $M_f$ Table 3) the persistence of resorption spaces is more accentuated than initially apparent—The bars at the bottom indicate that there is less cortex present in the corticoids than in the normals in terms of the ratio of the amount of bone present on cross section to the volume of space enveloped by the periosteum CA designates cortical area TA total cross section area This ratio is a sensitive index of growth or osteoporosis

In Table 2 the individual measurements of the corticoid group are listed In Table 3 the means standard deviations and standard errors of the corticoid patients are listed and compared to the norm as found in the group of 31 normal ribs referred to In Figs 1 and 2 the normal and corticoid group are compared to each other graphically

## RESULTS

The symbols used elsewhere for the features that were measured are included (6)

1) ($A_f$) The numbers of active osteoid seams mm are 0 28 in normal and 0 15 in corticoid groups of ribs If only the adult corticoid treated patients (cases 6-18) are averaged their value is 0 0?8 a reduction to 15 per cent of normal

2) ($A_r$) The numbers of resorption foci per $mm^2$ are 0 52 in the normal and 0 77 in the corticoid treated groups an increase of 48 per cent from normal

3) ($M_f$) The linear rate of mineralization of new lamellar matrix in mm/year at the average focus of active new bone formation is 0 31 in normal and 0 20 in corticoid bones These figures are from a study reported elsewhere (8 9) of measurements based on tetracycline labelled human bone Although a 30 per cent decrease was observed in some corticoid treated patients the number of patients in the study was small so the figures are tentative

4) ($M_r$) The linear rate of destruction of bone at a resorption front cannot be directly measured with our methods A lower limit is given by the ratio of ($A_r$) to ($A_f$) The reason is that, if both types of foci existed for the same time they would occur in equal numbers If one focus existed *twice as long as the other twice as many would be found* because at some time in internal remodelling each type of focus has been or will evolve to the other type

The ratio of $A_r/A_f$ reveals how much longer a resorption focus exists than a formation focus This assumes certain things which have not been established

One is the assumption that enough time has elapsed since onset of treatment with the corticoids for a steady bone state to develop Another is the assumption that the natural sequence of resorption followed by formation[1] is not altered by the corticoids

The $A_r/A_f$ ratio is listed in column 7 Table 2 It is much larger in the corticoid treated patients than in normals The normal ratio is 1 4 and can be calculated from the data in Table 3

5) ($S_f$) The mean specific surface of active osteoid seams in mm is 0 33 in normal and 0 42 in corticoid ribs The difference is below the borderline of significance ($p > 05$) because of the sparsity of active seams in the corticoid bones

6) ($S_r$) The mean specific surface of resorption foci in mm is 0 44 in normal and 0 49 in corticoid ribs This is not significantly different and the two may be assumed to be the same This means that the average resorption focus in these corticoid treated persons was normal in size

7) (k) The cortical cross section area in mm is 19 in normal and 14 8 in the corticoid ribs This means that the corticoid ribs are a little

[1] Which is the case in internal remodelling

osteoporotic compared to the norm which may be taken as evidence of an excess of endosteal resorption relative to endosteal formation The meaning of this measurement is that in one millimeter thick cross sections of ribs there are normally 19 mm³ of bone but in the corticoid treated group there were only 14 8 mm³ a decrease of 22 per cent from normal

DISCUSSION

The steroid treated group of patients is small and its individuals were afflicted with serious although varied medical and/or surgical problems So the preceding data and the following attempts at interpretation are not conclusive They are illustrative They show one way to get definitive answers from human bone and they may be correct It should be pointed out that previous attempts to define the cell dynamics in Cushing s syndrome have been difficult to interpret because of methodological problems The major uncertainties in this report are due to a limited sample which nevertheless is one of the largest in a quantitative histological study of Cushingoid bone yet reported

Now our interpretation

1) The corticoids cause (directly or indirectly) a dramatic decrease in the number of foci of new bone forming activity This is seen consistently in all bones from corticoid treated patients There is insufficient change in the size of these foci to offset the 85 per cent decrease in their number and a decrease is reported elsewhere in their individual rates of evolution (9)

The next inference naturally is

The steroids decrease the rate of bone formation This is in qualitative agreement with tracer based *in vivo* studies among them being those of *Heany & Whedon* (11) and *Rich Ensinck & Fellows* (17) Since our study suggests that this is due mostly to decrease in the *numbers* of formation foci it seems to us that the steroids primarily affected the mesenchymal cell population The result of this effect is not only a decrease in the numbers of formation foci it is probably also an absolute decrease in the numbers of osteoblasts (see *Sissons* (20))

2) If the values of the corticoid and normal groups in Table 3 are substituted into equation (2) assuming a value of unity for (k) the resulting numerical values for ($V_{fl}$) are 0 0048 for the corticoid treated and 0 039 for the normal ribs These numbers are the decimal part of the rib that would be duplicated as newly formed bone per year This

is termed the bone formation rate (9) and indicates that there is an 88 per cent decline from the normal to the corticoid state.

3) Assembling the resorption terms, it seems to us that there was suppression of resorption in the corticoid treated group. There are 7 patients in Table 1 who received corticoids a year or longer. Were resorption accelerated, there should have been little bone left due to enlargement of the marrow cavity. Yet there is little change in cortical cross section area in these 7 compared to the rest of the group, as column II, Table 2 reveals. Also had resorption been accelerated, the cortices should have become porous in these 7 due to enlargement of old resorption foci and the appearance of new ones. This was not observed. The increase in number to about 50 per cent over normal we interpret as the result of *accumulation* of foci waiting for the next phase (*i.e.* bone formation) rather than an increase in resorption rate. This conclusion is also in line with *Sisson's* report on the paucity of osteoclasts in this state (20). We freely grant the right of the reader to disagree with this interpretation.

## SUMMARY

The number of places where bone remodelling activity occurs was found to be depressed in ribs from 18 patients treated longer than 2 months with adrenal cortical steroids. This depression seems to arise from some change in the activity of the mesenchymal cell population which generates osteoclasts and osteoblasts.

The speed with which an individual formation focus evolves seems to have been depressed also in these ribs. This depression appears to arise from a change in the activity of the osteoblast population.

There was no evidence of increased bone resorption, and possibly a suggestion that resorption was decreased.

## RÉSUMÉ

Il a été constaté une dépression de l'activité de remodelage des os en un certain nombre d'endroits dans les côtes de 18 malades traités pendant plus de deux mois par stéroïdes de cortico-surrénale. Cette dépression semble découler de certaines modifications de l'activité de la population des cellules mesenchymales qui produisent les ostéoclastes et les ostéoblastes.

La rapidité avec laquelle se forme un foyer individual semble égale-

ment avoir diminue dans ces cotes Cette diminution semble provenir d un changement intervenu dans l activite des osteoblastes

Il ne semblait pas y avoir une resorption osseuse accrue et on peut meme supposer que la resorption avait diminue

## ZUSAMMENFASSUNG

Die Anzahl der Stellen in denen eine Knochenumbildungsaktivitet vor sich geht wurde bei Rippen von 18 Patienten die länger als 2 Monate mit adreno-cortikalen Steroiden behandelt worden waren als herabgesetzt gefunden Diese Herabsetzung scheint durch irgendeine Veränderung der Aktivitet der mesenchymalen Zellen die Osteoklasten und Osteoblasten bilden zu entstehen

Die Schnelligkeit mit der ein individuelles Bildungszentrum entwickelt wird scheint bei diesen Rippen ebenfalls herabgesetzt zu sein Diese Herabsetzung scheint von einer Veränderung der Aktivitet der Osteoblasten hervorgerufen zu werden

Keine augenscheinliche Zunahme von Knochenresorption war vorhanden doch handelte es sich moglicherweise um eine Verminderung der Resorption

## REFERENCES


1 *Bauer G C H Carlsson A & Lindquist B* Evaluation of Accretion Resorption and Exchange Reactions in the Skeleton Kungl Fysiogr Sällskap Lund Forhandl 25 1-16 1955

2 *Belanger C F & LeBlond C P* A Method for Localizing Radioactive Elements in Tissues by Covering Histological Sections with a Photographic Emulsion Endocrinology 39 8 1946

3 *Chalkley H W Cornfield J & Park H* A Method for Estimating Volume Surface Ratios Science *110* 295–297 1949

4 *Frost H M* Staining of Fresh Undecalcified Thin Bone Section Stain Technol 35 135–146 1959

5 *Frost H M* Preparation of Thin Undecalcified Bone Sections by Rapid Manual Method Stain Technol 33 273–276 1958

6 *Frost H M* Bone Remodelling Dynamics Charles C. Thomas, Springfield Ill., 1963

7 *Frost H M* Tetracycline Labelling of Bone and the Zone of Demarcation of Osteoid Seams Canad J Biochem. Physiol., 40 485–489 1962

8 *Frost H M* Mean Formation Time of Human Osteons Canad J Biochem Physiol 41 1307 1310 1963

9 *Frost H M* Measurement of Human Bone Formation by Means of Tetracycline Labelling Canad J Biochem Physiol 41 31 42 1963

10 *Ham A W & Leeson T S* Histology 4th ed J B Lippincott Co Philadelphia 1961

11 *Heaney R I & Whedon C D* Radiocalcium Studies of the Bone Formation Rate in Human Metabolic Bone Disease J clin Endocr Metab *18* 1246 1267 1958
12 *Kember N F* Cell Division in Enchondral Ossification J Bone Jt Surg 42B 824 1960
13 *Milch R A Rall D P & Tobie J E* Bone Localization of the Tetracyclines J Nat Cancer Inst *19* 8293 1957
14 *Milch R A Rall D P & Tobie J F* Flourescence of Tetracycline Antibiotics in bone J Bone Jt Surg *30A* 897–910 1958
15 *Owen M* Cell Population Kinetics of an Osteogenic Tissue Brookhaven Natl Lab publications #6737 6738 1963
16 *Quastler H & Sherman F G* Cell Population Kinetics in the Intestinal Epithelium of the Mouse Exp Cell Res *17* 420 1959
17 *Rich C Ensinck J & Fellows H* The Use of Continuous Infusions of Ca45 and Sr85 to Study Skeletal Function J Clin Endocr Metab *21* 611 623 1961
18 *Sedlin F Frost H M & Villanueva A R* Measurement of Resorption in Normal Rib by the Howship s Specific Surface Index Anat Rec *146* 201 1963
19 *Sedlin E* The Rate of Cortical Area/Total Area as a Measure of Osteoporosis in Ribs Clin orthop *36* 161 1964
20 *Sissons H A* The Osteoporosis of Cushing s Syndrome in Bone As A Tissue K Rodahl J T Nicholson & E M Brown Jr eds McGraw Hill Book C Inc New York 1960
21 *Villanueva A R Frost H M & Sedlin E* Bone Formation by the Osteoid Seam Index in normal Human Ribs Anat Rec *146* 209 1963
22 *Young R W* Regional Differences in Cell Generation Time in Growing Rat Tibiae Exp Cell Res *26* 562–567 1962
23 *Young R W* Nucleic Acids Protein Synthesis and Bone Clin orthop *26* 147 160 1963

Acta orthop Scandinav XXXV 185–201 1965

From the Department of Anatomy Karolinska Institutet Stockholm
(Head Prof T Petren M D )
and the Orthopaedic Clinic Sodersjukhuset Stockholm (Head A Hellstadius M D )

# TISSUE LAXITY AND ITS INFLUENCE ON POWER OF MUSCLE

*By*

A MARSK

The degree of hardness which a muscle expresses during palpation through the covering soft tissues has long been termed tonus or tone

There has been a great deal of discussion about this term however As early as 1931 *Sherrington* (1) claimed that the word tonus should be dispensed with since it embraces far too many different concepts Nevertheless it is still in use particularly in clinical circles *Reichel* (2) argues that the term "Ruhespannung is more adequate Against this the objection can be raised that it is difficult to achieve a state of complete rest Special attention must be devoted to the position of that part of the body where the muscle tone is to be appraised Using for example a standing individual to asses and compare the distribution of muscle tone in symmetrical segments of both halves of the body can lead to serious errors if an uneven distribution of the body weight over the lower extremities is not taken into consideration

There are diverse opinions meanwhile on the nature of the muscle s resting tension *Landowne & Stay* (3) define tonus as a long continued state of tension in a muscle maintained by activity of the contractile elements This corresponds most closely to the idea that tissue tension and its variations have their equivalents in gels of varying viscosity In contrast to this active theory there is the more "passive theory which upholds the decisive importance of the tissue elasticity in the muscle fibres and in the connective tissue around the sarcolemma and between the fibres where it in the form of endo-perimysium intertwines and surrounds the muscle It has long since been established that this network of connective tissue in intimate contact with the contractile element of the muscle affects the mechanics of the muscle

*Braus* (4) describes the connective tissue as the *skeleton* of the muscle and says of the septa which intertwine the muscle that sie verhindern die Faser über eine maximale Grenze anzuschwellen ohne die Dehnung des Muskels in der Längsrichtung zu hemmen *Hill* (5) maintains that "the main deformation of active muscle takes place in the passive series elastic element and *Ramsay* (6) also emphasizes the great importance of the interstitial tissue in the total elastic condition of the muscle *McKinley & Berkwitz* (7) consider that regard must be paid to the muscle fibres own elasticity and that a great deal in the matter of tonus is not attributable merely to a reflex mechanism by proprioceptive reflexes *Adams–Denny Brown–Pearson* (8) maintain that atrophic muscle fibres which do not properly fill their connective tissue capsules give the impression of being hypotonic musculature just as well trained muscles with large muscle fibres which thoroughly fill out their connective tissue capsules give the impression of possessing good tone

The nervously conditioned state of the muscle is transmitted by a somatic spinal reflex arc The receptor organs are primarily those stretch receptors which are found in the muscles (muscle spindles) and tendons (Golgi organs) and from which afferent impulses reach the spinal cord via the dorsal roots Through their poles the muscle spindles often make contact with the muscle fascia or the perimysium the intramural extension of which as endomysium intertwines the muscle both in its longitudinal direction and at right angles to it

The clinician quite often encounters patients with a manifestly low rest tension in their muscles As a rule this condition is accompanied by a general softness of the tissues and by joint flaccidity Varying attention has been directed to this within the different branches of medicine often enough however it is treated in the reports as a curiosity Most articles on the subject are by dermatologists and neurologists But this form of muscle hypotonia is probably of greater significance in orthopaedics than in any other branch of medicine Hypotonic patients constitute a large percentage of orthopaedic cases Papers on the subject by orthopaedists meanwhile are not very numerous

Based on material from the Dept of Physiotherapy at the Karolinska Sjukhuset *Andersson & Silfverskiöld* (9) have discussed the question of what they call the flaccid joint type though without going into its causes In an orthopaedic publication *J & R Hass* (10) have contributed a paper on the same subject though once again without attempting to analyse the causes They have called congenital joint flaccidity "arthrochalasis multiplex congenita These authors likewise point out that

this interesting clinical phenomenon has been sadly neglected in ortho paedic literature The French clinical journals describe joint flaccidity principally as laxite ligamentaire while in German journals we en counter the term die konstitutionelle Bänderschwache the sufferers of which "die Bänderschwächlinge reveal all manner of postural deformities of a statical origin due to gravity and loading besides varices and herniae The ability of these patients to stretch their joints excessively has given rise to the terms "Fingerkunstler and "double-jointed people Another term often encountered in the English langu age publications is Ehlers Danlos syndrome which is a collective cli nical term for the different forms of tissue laxity There are three clinical manifestations of the classical syndrome 1 laxitas cutis or cutis hyperelastica where the skin can be lifted up into large folds 2 laxitas articulorum sometimes demonstrating grotesquely stretchable joints 3 a curious frailty of the skin dermatorhexis which makes it very difficult to stitch a wound or incision in such a patient since the stitch simply breaks through the skin instead of holding it together On healing the wounds of these patients often leave an ugly keloid like scar This third part of the syndrome however ought to be rather seldom met with

Tissue softness and joint flaccidity is remarkably heredo familial The hereditary course has not been fully clarified It would seem that both sexes are equally affected

The joint flaccidity with abnormally large amplitudes of movement results in poor stability of the joint This instability sometimes as suming the proportions of transient subluxations predisposes to in congruence of the joint facets and eccentric wear of the joint cartilages

Those authors who consider that muscle hypotonia and joint flacci dity cannot be attributed solely to disorders in the neuro-muscular reflex mechanism turn as a rule to an inferior mesenchyma for the cause Mesenchymos fibrodysplasia or fibrodystrophia have been put forward as explanations This theory has support by the fact that children suffering from joint flaccidity often reveal blue sclerae a con dition thought to result from an unusually thin atrophic dystrophic sclera which permits the pigment rich and blood rich choroid to show through and give the sclera its blue shade Histological studies of the skin connective tissue and musculature of patients with tissue softness and joint flaccidity have not revealed any particular departure from the normal In cases of Ehlers Danlos syndrome some authors have revealed through electronmicroscopic studies certain fine structured

differences, for example in the intertwining of the collagenous and elastic fibrils. No definite evidence has been put forward, meanwhile, that there is any pathological significance attached to this. *Dammermann & Muller* (11) put forward as a reason "die Spannungsverlust und die Überdehnbarkeit der kollagenen Fasern . . . welche im Elektronmikroskop nachgewiesen werden konnten". The authors talk of "Tonus des kollagenen Gewebes" and mean here presumably the physical properties and qualities of the connective tissue. If the points of view concerning muscle tone were extended to embrace the tonus of the connective tissue as well, *i.e.* the physical properties such as elasticity and stretch, then the problem could only be dealt with from a biomechanical angle of approach.

Whether we regard the neuro-muscular theory as sufficient explanation for tonus, and somatic or functional disturbances of a most complicated, psychically modulated reflex mechanism as the reason for muscle tone disturbances, or prefer to regard the phenomenon as a matter of the tensile strength, say as a matter of quality, of the connective tissue in different individuals—or whether we consider that both these theories can be combined, possibly through a neuro-hormonal link, the problem as a whole has so many practical clinical aspects that any form of investigation in this field is bound to be watched with interest.

## AUTHOR'S INVESTIGATIONS

In an effort to acquire figures on the magnitude and variations in the hardness of muscles, where rest tension is a basic component, the following experimental method was worked out.

A plastic ring with an outer diameter of 2 cm and an inner diameter of 1 cm and a thickness of 1 cm was fastened with a special glue on to the skin over the muscle intended for examination. A small piston was inserted into the 1 cm hole. The piston was secured by two springs fixed in two diametrically opposite situated holes on the outer side of the ring (Fig. 1). By means of the springs it was possible to bring a light pressure to bear so that the piston was pressed in against the skin. When the muscle contracted, giving rise to varying states of hardness, the piston was pushed upwards to an extent that depended upon the degree of contraction. The plastic ring was also raised, of course, when the muscle contracted, but through the way in which the initial position was set—with the piston slightly pressed against the skin inside the ring—it was possible to register the difference in the position of the

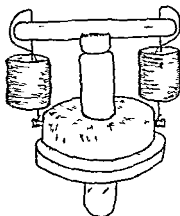


*Fig 1*

piston in relation to the carrying surface of the plastic ring during the different contraction states of the muscle

This method however was found to have certain complications which were difficult to overcome One of these was of a technical nature to find a dependable glue with a suitable joint If the joint was somewhat elastic the ring was more securely firm against the skin but on the other hand this elastic layer between the skin and the under surface of the ring took up too great a part of the upwards pushing force from the piston during the muscle s contraction which naturally made it impossible to use this sort of glue Of the different types that were tried Eastman 910 proved to be the most adequate although due to the relatively frail joint it was not possible to leave the test patient to his own devices for a prolonged time without risk of the plastic ring loosening It was reckoned that through relatively long term tests it would be possible to assemble information on the assumable changes in the degree and duration of the muscle s hardness This of course would call for a continuous registration of the course

When using this method for comparing results from different individuals the elasticity of the skin is one of the most important factors If the skin is extremely elastic a considerable degree of the measurement range is lost

The degree of skin elasticity which varies according to the individual may be regarded as also representative of conditions in other connective tissue in the individual The significance to muscle mechanics of the muscle s own connective tissue has already been pointed out On the

observation that extensive stretchability of the skin made my method less accurate it occurred to me that the elasticity factor might be of some significance to the degree of force deriving from a muscular contraction In other words it is possible that extensive elasticity leads to a loss of power during a muscular contraction Mechanically this could be explained by extensive elasticity in the connective tissue permitting excessive bending or deflection of the muscle fibres the more peripheral in the muscle the greater the loss Apart from this presumably unfavourable displacement in the direction of force of the muscle fibres resulting from their deflection there are also certain hydraulic aspects of the way in which the muscle works assuming that the contractile element is regarded as a viscous mass or gel contained in a connective tissue capsule The degree of effect in this system would be upset if the cylinder walls were too extensible Both for the vascularisation of the muscle and for the setting in action of the self regulator or the servo steering in respect to the reflex activated tension which the muscle spindle mechanism is reckoned to represent a certain degree of elasticity is of course required though we can assume that *there should exist an optimum for this In the case of individuals with a* pronounced degree of tissue softness clinically defined as hypotonic patients it is possible that the resistance met by the contractile mass of the muscle is too low and thus not optimal Previous investigations have not been able to prove that the reason for hypotonia is to be found somatically in defective muscle spindles or terminal nerve endings (12) or functionally in a defective nervous innervation

*Brown* (13) claimed during a test on the M retractor penis of a tortoise that if the muscle was made to contract against a compression of 270 atmospheres the singular isometric twitch doubles The reason for this was thought to be that through the counter pressure the contractile phase was prolonged

The planning of the continued investigation was carried out with a view to finding out what effect elasticity in the soft tissues surrounding *the muscles might have upon the magnitude of the power derived from* a muscular contraction

## METHOD

There are certain difficulties attached to finding a muscle or a group of muscles suitable for what one intends to study As a rule the force output at the joints is a summation effect of several muscles Thus for example the force involved when the sole of the foot presses down on a plate is the result of the efforts of more muscles than just the M triceps surae For my investigations I selected the thenar group

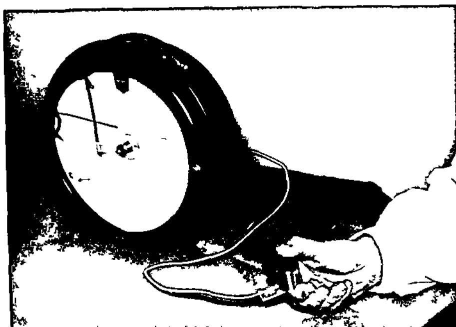


*Fig 2*

These muscles have a fairly selective effect upon the small joints The risk of ir relevant ad lenda of any significance from other muscles is negligible As a working test I selected the grip made by the thumb when its terminal phalanx is pressed against the radial side of the forefinger s middle phalanx This pinching action makes great demands of the thenar musculature When performing this grip the effect of the thuml s long flexor can l e regarded as a constant component The fingers are hel l seml flexe l and the forefinger is supported against the remaining fingers (Fig 2) The pre sure is conveyed to an elastic bell ows via a spherical button and the counter pre sure via a concave grooved part of the under surface of the l utt n sup p rted on the middle phalanx of the forefinger From the bellows the pre sure is hy lraulically tran mitted to a pressure receiver and registering instru ment[1] The instrument is fitted with a printer which shows the pressure variations al as a function of time l y means of a graph which is rotated b electricit (Fig 2) The design of the take up comp onents gives the best p ssil le assurance that for each pati nt the same lever is used during b th parts of the experiment as per below an l al o that lirection of the app lied pressure is the same in both parts of the experiment The patient is requested to exert maximum pres ure The above experi ment a p inte l out is divided int two parts One where the thenar mu culature is permitted to swell freel and one where this is restricted as per below A hindrance to the mu cle sp ntane ous configuration changes during the contraction can be

[1] Thi equip ment was manufactured by A B Nordi ka Armaturfal rikerna Lin k ping St ckh lm un ler the regi tration number NAF 3 00

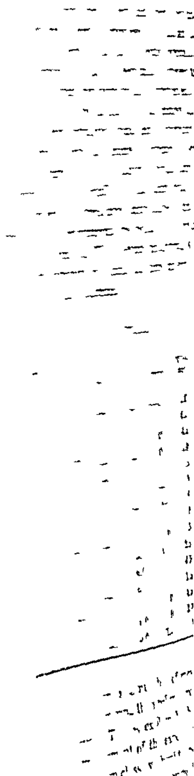
observation that extensive stret
less accurate it occurred to m
some significance to the degr
contraction In other words it is
to a loss of power during a m
could be explained by extensive
mitting excessive bending or de
peripheral in the muscle the g
sumably unfavourable displacem
muscle fibres resulting from th
hydraulic aspects of the way in w
the contractile element is regard
in a connective tissue capsule Th
be upset if the cylinder walls v
cularisation of the muscle and fo
gulator or the servo-steering in r
which the muscle spindle mechani
degree of elasticity is of course r
there should exist an optimum for
pronounced degree of tissue soft
patients it is possible that the r
of the muscle is too low and thus
have not been able to prove that the
somatically in defective muscle s
(12) or functionally in a defective

*Brown* (13) claimed during a t
tortoise that if the muscle was mad
of 270 atmospheres the singular iso
for this was thought to be that thro
tractile phase was prolonged

The planning of the continued inv
view to finding out what effect elasti
the muscles might have upon the m
a muscular contraction

METHO

There are certain difficulties attached to f
suitable for what one intends to study As a
summation effect of several muscles Thus f
sole of the foot presses down on a plate is th
than just the M triceps surae For my inve



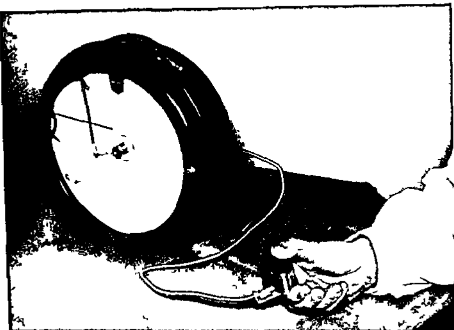


*Fig 2*

These muscles have a fairly selective effect upon the small joints The risk of irrelevant addenda of any significance from other muscles is negligible As a working test I selected the grip made by the thumb when its terminal phalanx is pressed against the radial side of the forefinger s middle phalanx This pinching action makes great demands of the thenar musculature When performing this grip the effect of the thumb s l ng flexor can be regarded as a constant component The fingers are held semi flexed and the forefinger is supported against the remaining fingers (Fig 2) The pressure is conveyed to an elastic bellows via a spheri al button and the c unter pres ure via a conca e grooved part of the under surface of the butt n u pported on the middle phalanx of the forefinger From the bellows the pres ure is hydraulically transmitted to a pressure receiver and registering instrument[1] The instrument is fitted with a printer which shows the pressure variations al o as a functi n of time by means of a g aph which is rotated by electricity (Fig 2) The design of the take up components gives the best p ssible assurance that for each patient the ame l ver is used during both parts of the experiment as per below and al that direction of the applied pre ure is the same in both parts of the experiment The patient is requested t exert maximum pres ure The above experiment a p inte l out is di ided into two parts One where the thenar musculature is permitted to swell freely an l one where thi is restricted as per l el w A hindrance to the mu cle s pontane us configuration changes during the contraction can be

[1] Thi equipment was manufactured by A B Nordiska Armaturfabrikerna Lin k ping Stockh lm under the regi trati n number NAF 3 00

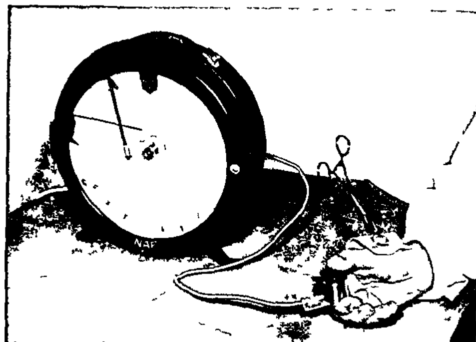


*Fig. 3*

achieved by decreasing the tissue space within which the muscle in different sized units of contractile masses swells. Collectively all these spaces constitute the muscle's real compartment. Reduction can be achieved through lessening the size of the tissue capsule which takes part in the stretching action when the muscle contracts. Only the peripheral capsule around the muscle, i.e. the skin, is of course available for such a measure for in order to reduce the muscle fascia as well an operation would be necessary.

The reduction of the skin is achieved as follows. A thin rubber sheet is placed on the skin dorso-radially to the thumb's metacarpal bone. The skin and its accompanying rubber sheet is lifted up in a fold parallel to the metacarpal bone. One or a couple of pairs of grooved tongs of the type employed in anesthesiology to draw the tongue forwards are used to lift up and secure this fold (Fig. 3). The object of the rubber sheet is to protect the skin. It is of course not possible to avoid a certain slipping of the raised skin during the contraction of the muscle. The patients were not informed beforehand of the object of the experiment which was described simply as a study of muscle physiology.

Since the degree of variation in muscle power during the two existing experimental conditions may be so slight that it can escape detection in a rested muscle through the method described, the experiments were carried out on fatigued muscles. The fatigued muscle has very little reserves of power left and consequently it is more sensitive to changes in its normal environment. The patients thus began by making a series of pinching actions during the experiment with a request to maintain a constant pressure level as long as possible. The apparatus was so placed that it

could only be read by the person directing the experiment By studying the graph made by these introductory tests the fatigue progress could be watched and when this reached a suitable level the test was begun The two phases of this with and without stretched skin followed directly after each other the only interval between being the time needed to lift up *the fold of skin with the protective rubber sheet* and apply the pair of tongs Two such complete experiments were made on each patient There was the same interval between the final preliminary fatiguing test and each phase of the experiment In order to test the theory—of a connexion between the resistance met by a muscle during its contraction and its power—as severely as possible the stretched skin phase was always the latter one

The following points must be strictly observed if the experiment is to be correctl carried out

1 The patient must participate whole heartedly and do his utmost all along This is a prerequisite of the entire method

2 The same grip must be maintained on the pressure giving apparatus throughout the experiment even when the skin fold is raised and the tongs secured This does not mean of course that the muscle should not be relaxed when the patient is n t actually engaged in the pinching action The pinching action furthermore should not be abrupt and intense it should be gentle and persistent.

3 A proper change in the size of the muscle compartment must be achieved This means that the raised fold of skin shall be as large as possible and must remain in a raised position b means of a stead grip with the tongs A certain problem may arise here insomuch that this pr cedure may hurt or trouble the patient some hat despite the protective rubber sheeting causing him to reduce the strength of his effort The patient should thus be questioned on this point

The necessity of being able to change sufficiently the conditions around the muscle in phase II of each experiment means that a normal patient cannot be used since the normal individual does not have sufficient "surplus" skin

## MATERIAL

The investigation was carried out on human subjects These were not selected beyond the rejection of individuals who were either too old or too retarded mentally to be capable of co-operating in the procedure or who showed unsatisfactory passivity during the investigations and who were generally adjudged to be unlikely to co operate

The material comprises 15 individuals 10 females and 5 males selected at random from the comparatively large group of people who clinically reveal tissue laxity As a criterion here laxitas cutis and laxitas articulorum were chosen In no case was the former the result of rapid loss of weight The ages of the patients varied between 14 and 67

## RESULTS

The results of the experiments are shown in Table 1 Some diagrams are shown in Figs 4–6

The circular diagram which has a circuit time of 4 minutes shows

along the radial arcs pressure in cm and periphery time The distance between the concentric circles represents 0 1 kg and the smallest peripheral scale unit 2 5 seconds In the objective appraisal of the measurement results comparisons have been made between the output amplitudes *i e* the maximum pressure value shown in each part experiment Here the quarter values are adjusted to the nearest 1/2 or 1/1 unit value upwards in the parts without tongs and downwards with Amplitude has been measured from the nearest common 1/2 or 1/1 circle and is shown in the column headed without for the parts without tongs and in the column headed with for the parts with tongs d means the difference between the measured amplitudes 1 and 2 refer to the first and second sets of experiments respectively $M_d$ means the arithmetical *mean value of* $d_1$ *and* $d$ *The electric motor was stopped between each* phase in the experiment and thus the time intervals between the phases are not shown on the diagram

TABLE 1

| Patient | Sex | Age | Without | With | Difference | Without | With | Difference | Mean difference |
|---|---|---|---|---|---|---|---|---|---|
| I | ♀ | 20 | 2 5 | 2 0 | —0 5 | 1 0 | 2 0 | 1 0 | 0 75 |
| II | ♀ | 17 | 1 5 | 3 0 | 1 5 | 0 5 | 6 0 | 5 5 | 3 50 |
| III | ♀ | 51 | 1 0 | 1 5 | 0 5 | 4 5 | 5 5 | 1 0 | 0 75 |
| IV | ♀ | 67 | 2 0 | 2 5 | 0 5 | 1 0 | 2 0 | 1 0 | 0 75 |
| V | ♀ | 61 | 2 5 | 5 0 | 2 5 | 2 5 | 5 5 | 3 0 | 2 75 |
| VI | ♀ | 44 | 4 0 | 6 0 | 2 0 | 5 0 | 5 0 | 0 0 | 1 00 |
| VII | ♂ | 47 | 0 5 | 2 0 | 1 5 | 2 0 | 3 5 | 1 5 | 1,50 |
| VIII | ♂ | 48 | 3 0 | 5 5 | 1 5 | 5 0 | 6 5 | 1 5 | 1 50 |
| IX | ♀ | 28 | 2 0 | 5 0 | 3 0 | 3 5 | 5 0 | 1 5 | 2 25 |
| X | ♂ | 14 | 5 0 | 5 5 | 0 5 | 2 5 | 3 0 | 0 5 | 0 50 |
| XI | ♂ | 54 | 4 5 | 6 0 | 1 5 | 4 5 | 5 5 | 1 0 | 1,25 |
| XII | ♀ | 53 | 2 0 | 6 5 | 4 5 | 1,5 | 2 0 | 0 | 2,50 |
| XIII | ♀ | 3[illegible] | 5 0 | 7 0 | 2 0 | 4 5 | 7 0 | 2 | [illegible] |
| XIV | ♀ | 39 | 4 0 | 6 0 | 2 0 | 3 0 | 4 5 | 1 | 1 [illegible]5 |
| XV | ♂ | 28 | 3 5 | 5 0 | 1 5 | 2 0 | 2 5 | 0 5 | 1 0 |

For each patient there is a number of measurements which show a *certain variation both during the preliminary fatiguing test* and during the main experiment This is explainable biologically Meanwhile on account of the arrangement of the experiment two of these measurements belong to a certain class "without tongs and two to a class "with tongs If the arrangement of the experiment was of no importance to

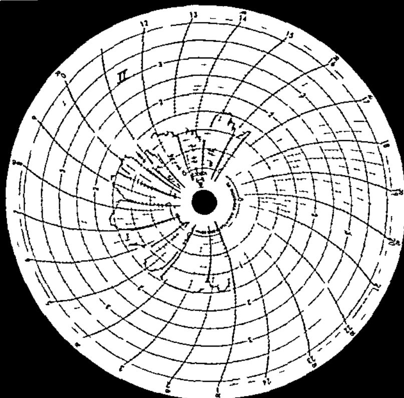


*Fig. 4*

the measurement values the difference between the mean figure for "without tongs" and the mean figure for "with tongs" would vary at random about 0, i.e. in the long run equally many positive and negative differences could be expected. In a sample group of 15 individuals there were 15 plus values, which by chance occurs only once in 32768, i.e. approx. 0.00003 ($2^{-15} \approx 0.00003$).

## DISCUSSION

The investigation has shown that in the case of the hypotonic individual, if resistance is set to the muscle during its contraction, thus restricting its swelling, then its effect increases. The change in the muscle's environment brought about by the investigation method would not seem to be such that the subsequent conditions differed from the

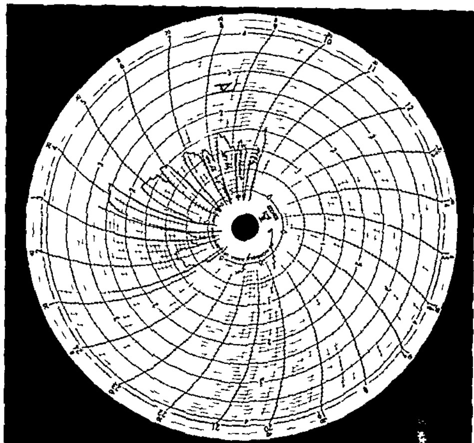


*Fig 5*

conditions regarded as normal in non hypotonic patients The exogenously achieved changes in pressure in the muscle compartment should within certain limits bring about an increase of muscular effect in any individual The resistance to the muscular contraction determining the pressure values within the muscle compartment should not of course be so great that the circulation and nervous status of the muscle and its surroundings is impeded An optimal pressure value in the muscle compartment corresponding to each single performance and an integrated elasticity optimum for the entire muscle compartment is conceivable In hypotonic individuals the elasticity factor in this respect would not be optimal but rather too great whereby their muscles would have to work constantly against too low a resistance The method in the investigation whereby the presumable pressure increase in the muscle compartment was achieved implied in practice a decrease

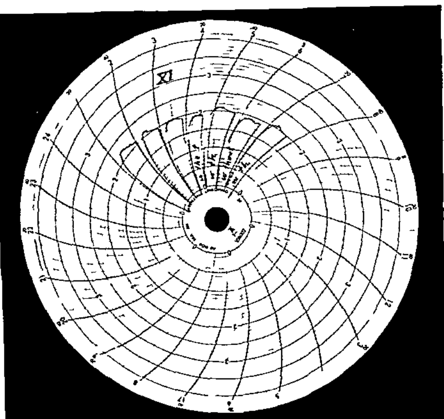



*Fig 6*

in the muscle compartment's volume This assumes that the term muscle compartment is used in its broadest sense implying all the tissue spaces affected by the configuration changes which occur during muscle contraction The method of raising the skin can be said to compensate for one of the most obvious clinical manifestations of the hypotonic patient *i e* "surplus skin There is no reason to assume that it would be an advantage for the non hypotonic if his muscle compartment were restricted From being an advantage for hypotonics a limit is passed where the longterm effect of pressure increase becomes negative in the non hypotonic individuals

It cannot be assumed that the raising up and pinching of the skin would through a change in the proprioceptive reflexes decrease the threshold for stimulation of the muscle and result in an increase in the muscle's effect In experiments it has not been possible to bring about

an increase in the muscle's effect merely through pinching the skin without at the same time holding it back during the contraction of the muscle.

That effect increase derives from increased contraction power in the muscle and not from conceivably more favourable power directions over the affected joints is confirmed by the fact that lesser changes in the degree of the thumb's rotation, changes of a magnitude which might conceivably accompany the holding off of the skin, do not bring about any increase of effect in the muscle during the course of the test, the pinching action of which consists mainly of opposition between thumb and forefinger.

On a basis of the way in which the method has been worked out it has not been possible to derive any figures on the pressure within the muscle compartment or on the degree of stretch in the skin above the muscle in the two phases of the experiment. Investigations in this direction will continue.

In view of the fact that people exhibiting tissue laxity are very often considered to be psychasthenics and that they display increased fatigue, it would have been interesting to have used the test to get an idea of their endurance, in order to see if there is any difference in endurance between the two conditions around the muscle which existed during the experiment. In the light of the results which have been derived it is not unlikely that the increased weariness can be ascribed, at least to some extent, to muscle mechanics. As can be seen from the diagrams, however, planimetric or other comparisons between surfaces would lead to absurd conclusions. This is because the threshold values for giving up, i.e. the time factor, varies so greatly from individual to individual. It is impossible to demand of a patient such a maximal prolonged tension as would be required for the test to give reliable endurance values. Furthermore, the revival time, if the test was also to be used as an endurance criterion, would be so prolonged that further false sources would seriously upset its course and interfere with the process of making comparisons of the muscle activity during two different conditions around the muscle.

## CONCLUSION

In his investigations the author has only desired to show that in patients exhibiting tissue laxity an increased resistance to muscular contraction—within the limits established by the experiment—seems

to result in increased momentary effect The attached diagrams are not intended to give detailed information

The clinical evaluation of the results should be made carefully Apart from the suggested connection between asthenia and increased fatigue and the findings which have been made it is possible that the unquestionably favourable effect of the corset in cases of spinal insufficiency is not only a result of the immobilizing effect of the corset It is likewise possible that in certain branches of physical sports empirically derived experience (for example the fact that among weight lifters a body belt can improve performance) may have a genuine basis

## SUMMARY

In individuals presenting tissue laxity and softness (people belonging to the clinical cadre of subjects with Ehlers-Danlos syndrome also termed Bindegewebsschwächlinge or said to exhibit laxite ligamentaire ) experiments have been made on their power of muscle contraction

The muscle or group of muscles under investigation has been the thenar musculature and the function test a pinching action of the thumb against the forefinger

The pressure thus evoked has been transmitted directly to and registered by an apparatus and the course has been visualized on a graph by means of a printer

The maximum contraction force of the muscle has been investigated in respect to two milieus

1 during normal conditions

2 when the muscle during its contraction has been prevented from swelling freely by lifting up a fold of skin in the immediate vicinity of the muscle and holding this fold steady back during the muscle contraction thus attaining a sort of shrinking of the muscle compartment —if this latter word is considered in its broadest sense

It would seem that this latter procedure—in conditions existing during the experiments and in individuals presenting tissue laxity—will produce a greater contraction power of the muscle The reasons for this fact are discussed

## RESUME

Des expériences ont été faites concernant le pouvoir de contraction des muscles chez des individus présentant une laxité et un defaut de tension des ligaments (appartenant au cadre clinique des sujets pré

an increase in the muscle's effect merely through pinching the skin without at the same time holding it back during the contraction of the muscle

That effect increase derives from increased contraction power in the muscle and not from conceivably more favourable power directions over the affected joints is confirmed by the fact that lesser changes in the degree of the thumb's rotation changes of a magnitude which might conceivably accompany the holding off of the skin do not bring about any increase of effect in the muscle during the course of the test the pinching action of which consists mainly of opposition between thumb and forefinger

On a basis of the way in which the method has been worked out it has not been possible to derive any figures on the pressure within the muscle compartment or on the degree of stretch in the skin above the muscle in the two phases of the experiment Investigations in this direction will continue

In view of the fact that people exhibiting tissue laxity are very often considered to be psychasthenics and that they display increased fatigue it would have been interesting to have used the test to get an idea of their endurance in order to see if there is any difference in endurance between the two conditions around the muscle which existed during the experiment In the light of the results which have been derived it is not unlikely that the increased weariness can be ascribed at least to some extent to muscle mechanics As can be seen from the diagrams however planimetric or other comparisons between surfaces would lead to absurd conclusions This is because the threshold values for giving up i e the time factor varies so greatly from individual to individual It is impossible to demand of a patient such a maximal prolonged tension as would be required for the test to give reliable endurance values Furthermore the revival time if the test was also to be used as an endurance criterion would be so prolonged that further false sources would seriously upset its course and interfere with the process of making comparisons of the muscle activity during two different conditions around the muscle

## CONCLUSION

In his investigations the author has only desired to show that in patients exhibiting tissue laxity an increased resistance to muscular contraction—within the limits established by the experiment—seems

Schwellung verhindert war Auf diese Weise erhielt man eine Art von Schrumpfung des Muskelfaches – wenn man den letzteren Ausdruck in seiner weitesten Bedeutung versteht

Es scheint dass das letztere Vorgehen – unter den vorliegenden Versuchsbedingungen und bei Personen die Gewebsschlaffheit aufwiesen – eine grössere Kontraktionskraft des Muskels hervorbrachte Die Gründe für diese Tatsache werden besprochen

## REFERENCES


1 *Weddell C et coll* Cit "Brain" 67 178 1944
2 *Reichel H* Muskelphysiologie Springer Verlag 1960
3 *Landowne M & Stay R* Tissue elasticit p 201 J W Remington Ed., Washington 1957
4 *Braus H* Anatomie des Menschen p 69 Springer Verlag Berlin 1921
5 *Hill A V* Cit "Tissue elasticity" p 90
6 *Ramsay R W* Cit ibid p 94
7 *McKinley C Berkwit* Cit "Brain" 67 178 1944
8 *Adams-Denny Brown-Pearson* Diseases of the Muscles New York 1953
9 *Andersson A & Silfverski ld V* Nordisk Medicin 47 873 1952
10 *Hass J & R* J Bone Jt Surg 40 4 3 19 8
11 *Dammermann H J & Müller W* Chirurg 26 542-545 1955
12 *Coers C & Woolf A L* The Innervation of Muscle p 115 Blackwell Oxford 19 9
13 *Brown D E S* Cit Reichel H Muskelph siologie p 139

Acta orthop Scandinav XXXVI 209–211 1965

From the Coast Hospital at Stavern Norway
(Former head H Støren present head K Hadland)

# CONGENITAL ANKYLOSIS OF THE ELBOW

## *Late Results in one Operated Case with Bilateral Ankylosis*

*By*

H STØREN

Congenital ankylosis of the cubital joint is extremely rare When reporting one case *Romanus* (1933) had been able to collect only 23 cases formerly described in the literature *Frostad* (1940) reported five cases of bilateral ankylosis in adults They all came from two families who lived in the same district (More) but without known relationship between the families

This author (1946) reported on bilateral cubital ankylosis in two baby sisters from the same district as *Frostad*s patients The grand father of the two children had three brothers suffering from the same disorder The case to be reported here apparently occurred quite isolated with no family history of similar cases and living far from the district of the other reported cases (Vestfold)

### *Other Malformations*

In the cases reported earlier by *Frostad* and the author no malfor mations other than the ankylotic elbow were seen

*In several of the cases collected from the literature by Romanus,* however also other defects had been described in the hands fingers or fore arms such as concrescence of metacarps absence of metacarps or fingers proximal or distal ulnar defects and shortening of the fore-arm or the upper arm In *Romanus* own case the affected arm was half as long as the sound arm

In the present case also cubital ankylosis was one of several con genital defects Ankylosis of tarsal joints with varus deformity of the feet symmetrical absence of the first interphalangeal joint in 2–5

fingers and ankylosis of the carpal joints The ankles and wrist joints were normal

### *Anatomical Findings*

In all of the formerly reported cases except one the radius had been found to be the chief bone in the formation of the ankylosis merging broadly with osseous connection directly into the humerus In one case the ulna was ankylotically joined with the humerus while the radius articulated freely with both In all the cases reported from Norway (eight cases including the present case) the radius has formed a broad ankylosis with the ulna and has been the dominating bone of the fore-arm Of the two cases formerly described by the author one had no ulna at all In both cases the malformation was bilateral

In none of my three operated cases (6 elbows) could epiphysial lines be demonstrated in any of the bones at the elbow The brachialis muscle was so poorly developed that its presence at operation could not be decided with certainty Biceps the long head of triceps and the muscles of the fore-arm originating at the humerus were all present This finding is not surprising as these muscles also exert their effect on the shoulder and the wrist joint respectively and thus maintain some activity despite a stiff elbow

The presence of these muscles is of the greatest importance to a successful operative treatment of a congenital ankylotic elbow

### *Treatment*

In schools of surgery and in textbooks it seems to be an established rule that in cases of congenital ankylosis of the elbow arthroplasty should be postponed until the patient reaches adult age partly because of the close relationship between the epiphysis and the joint but especially because of the difficulties connected with the after treatment in children The finding of absent epiphysial lines seems to cancel the first problem It is the aim of this report to demonstrate that the second problem may also be overcome

The need for treatment is made evident by *Frostad's* description of his five adult patients "Certainly the ability to work is surprisingly good even in occupations demanding great exertion but there are a number of important daily tasks which these five patients cannot perform For example they cannot wash the face or neck the upper

part of the chest or back They cannot shave wash their teeth or comb their hair They cannot button of their coats or the upper part of the vest They all have difficulties in eating They have to bend the head forward in order to meet the spoon or fork

*Faced with these adult patients Frostad took a rather pessimistic* view of the possibility of restoring good function by operative treatment The possibility of fashioning a new joint by operation has been discussed but not tested It must be assumed that an attempt to do so would be rather fruitless—chiefly because the muscles that should move the joint are completely atrophied

When I undertook to operate on the two children in 1946 (an operation which I could not see had been done before in similar cases) it was because I felt that the operation should be performed in early childhood before inactivation atrophy of the muscles had time to occur I considered this factor important enough to justify operation despite the considerable technical difficulties met with in these very young patients as well as the problems encountered in after treatment when active exercises of the muscles are mandatory

The results in these two first operated cases were discouraging After four years one elbow in each patient had again become stiff the other showed a movement from 90 –130 The results were identical in both patients

The result in the present case was more encouraging and will be described below

## CASE REPORT

A 4 months old girl with bilateral congenital ankylosis of the elbow was admitted to the hospital in 1950 She also had other congenital defects of bones and joints which have been described above Roentgenogram (Fig 1) of the left elbow revealed a broad synostosis between the radius and the humerus The ulna was separated from both humerus and radius by a well defined slit The olecranon was absent In the right elbow (Fig 2) there was a broad synostosis between the humerus and both the radius and the ulna the latter being very poorly developed No epiphysial lines were present in any of the bones at the elbow Despite this fact she had no marked shortening of the arms Possibly a compensatory increase of growth may have occurred at the upper epiphysis of the humerus and the lower *epiphysis of the radius*

1) On Feb 14 1950 an *arthroplasty of the right elbow* was performed using the dorsal longitudinal incision of Langenbeck (this incision has been used in all m cases) A free graft of fat from the abdominal wall was used as interposition material In accordance with the findings at the roentgenogram a solid bony connection between the ulna and the humerus was also found at operation From the

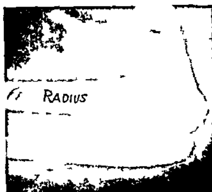



*Fig 1*

Congenital bilateral ank losis of the elbow Roentgenogram of the left elbow at age four months At operation at the age of one year (arthroplasty) was found a cartilaginous connection between the ulna and the humerus A trochlear notch was fashioned on the ulna and a matching trochlea on the humerus

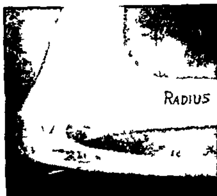



*Fig 2*

Roentgenogram of the right ankylotic elbow at the age of four months just before the operation which was performed when the child was 4½ months old Two re operations had to be performed to obtain the result shown in Fig 3

roentgenogram one may be led to the conclusion that the proximal end of the radium is cylindrical as in normal cases As in most of these cases however the bone at operation was found to be flattened from one side to another like a comb and was sclerotic and very hard to chisel The wound healed primarily and the patient could leave the hospital after the mother had been instructed how to exercise the elbow at home On doing this she noted after a while that the child cried during the elbow exercises but she continued the manipulations as before until one day a marked swelling and stiffening of the joint devel ped evidently due to hemorrhage N fracture c uld be demonstrated but the exercises had to be cancelled and ankylosis was re established in a 110 flexion position

2) On June 30 1950 (the child was now one year old) an *arthroplasty of the left elbow* was performed The synostosis between the radius and the humerus was chiselled through and about 15 mm of the proximal end of the radius resected The volar prominens at the lower end of the humerus was chiselled off A cartilagin us connection wa found between the ulna and the humeru A tr chlear n tch was fashioned on the ulna and a trochlea to match on the lower end of the humerus A graft of fa cia from the thigh was sutured into the new joint with catgut After the operati n the ell w could be flexed 90 + 20 and be fully extended The woun l healed primarily

3) On June 28 1957 (seven years after the f rst operation the patient aged 8 years) a *second arthroplasty of the r ght elbow* was performed As interposition material this time wa u e l a full kin graft (acc rding t hall ) After the operation the elbow could be flexed 90 + 40 The operation had been performed with

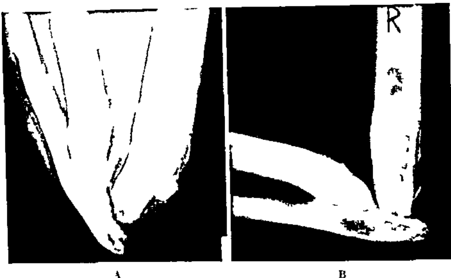


*Fig 3*

Congenital bilateral ankylosis of the elbow 13 years (left elbow) and 6 years (right elbow) after operation The right elbow was operated three times because of relapse of the ankylosis Flexion L 85 R 90 Extension L 90 + 35 R 90 Note how well the movements of one arm fill the lack of movement in the other With the right hand she can reach her head and upper part of the body with the left the lower part of her body In one picture the bulk of the biceps is shown under flexion against resistance

out using a tourniquet and a p o roentgenogram revealed a small fragment of bone lying in front of the radius which had not been discovered at operation This bone fragment later joined in osseous connection with both the radius and the humerus and ankylosis was re established

4) On October 10 1957 (four months after the last operation) a *third arthroplasty of the right elbow* was performed A solid osseous connection between the radius and the humerus was found at operation Only a small piece of the full skin graft from the last operation could be recognized which on microscopy showed necrotic skin with rejected epithelium About 12 mm of the proximal end of the radius was resected As interposition material a flap of fat from the abdominal wall was again used and sutured in place with catgut Postoperatively the patient at the age of eight years could be persuaded into active exercises and after two




A B

*Fig 4–A* Roentgenogram of the right elbow in maximal flexion after the last operation at the age of eight years The elbow was operated on the first time at the age of 4½ months

*Fig 4 B* The same as in Fig 4–A but with the elbow in maximal extension

months she could actively bend her elbow 90 + 60 and extend to 90 She could pronate 40 and supinate 15

On *follow up examination* October 1960 13 years after the operation of the left elbow and 6 years after the last operation of the right elbow was found (Fig 3)

Right elbow Flexion 90 + 60 – extension to 90 (Fig 4 A and B)
Left elbow Flexion 85 – extension 90 + 3 (Fig 5 A and B)

The roentgenogram of the left elbow shows that flexion could have been improved by trimming the proximal end of the radius which is pushed against the lower end of the humerus in maximal flexion of the joint However the patient was quite content with her elbow and wanted no more operations The change in the mutual caliber of the two bones of the fore arm towards normality was remarkable It may further be seen from the pictures in Fig 3 how well the movements of one arm fill the lack of movements of the other thus enabling the patient to meet the basic needs of daily life The right arm has normal flexion but cannot be extended past 90 The left arm has flexion

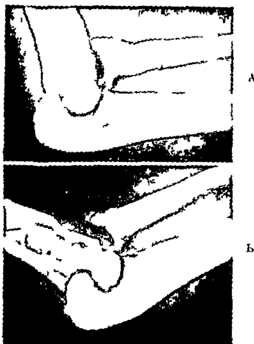



*Fig 5–A* Roentgenogram of the left elbow 13 years after operation (operated at the age of one year) Flexion which is limited by the proximal end of the radius pushing against the humerus could have been improved by another operation Note change of the mutual size of the fore arm bones towards normality

*Fig 5–B* The same as in Fig 5–A but with the elbow in maximal extension Extension is limited by the ulna (olecranon) pushing against the dorsal aspect of the humerus and could have been improved by another operation The patient however is quite content with the arm and wants no more operations

only to 85° but may be extended to 125 She thus is able to reach her mouth neck both ears and upper part of her body with her right hand With the left she can reach the lower part of her back and abdomen with the genitals

SUMMARY

The author in 1946 reported on two cases of congenital bilateral ankylosis of the elbow which he had operated in 1943 The results were rather discouraging Of the four operated elbows two (one in each patient) had relapse of ankylosis two had a maximal movement of about 30°

A report is given on one patient with congenital bilateral ankylosis of the elbow who was operated for the first time in 1950 at the age of 4½ months when arthroplasty was performed in the right elbow This elbow had to be re operated twice the last two operations being performed at the age of eight years The left elbow was operated at the age of one year and no re operations were necessary

Follow up examination 13 years (left elbow) and 6 years (right elbow) after the operation showed rather encouraging results The patient could make very good use of her arms and was able to meet nearly all the basic needs of daily life The results are demonstrated by photographs and roentgenograms

The optimal time for operation is discussed Whether to operate in early childhood in spite of the difficulties encountered at this age at operation and in after treatment in order to avoid inactivation atrophy of the muscles which would be expected at an older age in unoperated cases Or to operate when the child has become older when better anatomical conditions at operation and better cooperation from the patient during after treatment may be expected

The author has operated on all his cases (three patients six elbows) in early childhood because he felt that avoidance of inactivation atrophy was of paramount importance However after observing good results after re operation of a re ankylosed elbow at the age of eight years the author now feels that operation at this age may be at least as good as in early childhood

The occurrence of inactivation atrophy of the muscles around the elbow *may have been overestimated especially of the muscles that in* addition to the elbow exert their action upon the neighbouring joints (wrist and shoulder)

The author advocates that operative treatment be considered in all *cases of bilateral congenital ankylosis of the elbow* no matter what the age of the patient

## RESUME

L opération pour l ankylose congenitale du coude n avait pas ete mentionnée dans la litterature lorsque l auteur communiqua en 1946 deux cas bilatéraux opéres en 1943 L auteur n a pas non plus trouvé plus tard de communications sur des cas de cette maladie qui auraient *été opérés*

Les quatre articulations du coude opérées en 1943 ont en ce qui concerne les articulations du coude gauche chez les deux malades don

né un resultat negatif avec raidissement L articulation du coude droit a chez les deux malades conserve une mobilite limitee de 30 degres Elles ont toutes été operees a l age de nourrisson

Le troisieme cas que l auteur a opere en *1950* et qui est rapporte ici a donne un bon et durable resultat tres utile pour le malade Chez ce malade l articulation du coude droit a éte operee alors que la fillette etait agee de 4 mois et demi, le coude gauche alors qu elle avait 12 mois Il a fallu reoperer le coude droit 3 fois la derniere fois lorsque la fillette etait agée de 8 ans Le résultat apres 6 et 13 ans respectivement est decrit et il en est fait la demonstration par des illustrations et des radiographies

L auteur discute la question de savoir s il convient d operer a l age de nourrisson alors que l on peut supposer que l atrophie d inactivite des muscles n est pas encore tres prononcee ou s il faut attendre que l enfant soit un peu plus age alors que l operation est techniquement plus facile a executer et que les conditions du traitement post opératoire sont plus favorables

En ce qui concerne l atrophie d inactivite l auteur pense en se basant sur les experiences du dernier cas qu elle n augmente apparemment pas tres rapidement dans les muscles des trois elements de l articulation si importante pour le pouvoir de flexion et de tension du coude Le resultat chez cet enfant de 8 ans – il est vrai reopere pour la troisieme fois dans l articulation du coude droit – semble montrer qu il est possible qu une operation a cet age soit plus favorable

Dans tous les cas il ne convient pas de rejeter le traitement chirurgical comme n ayant aucun espoir de reussite meme chez les enfants plus ages souffrant d ankylose congenitale bilaterale du coude

## ZUSAMMENFASSUNG

Die Operation der angeborenen Ankylose des Ellbogengelenkes war nicht in der Literatur besprochen als der Verfasser zwei doppelseitige operierte Falle im Jahre 1946 mitteilte (operiert 1943) Aber auch spater hat der Verfasser keine Mitteilungen von operierten Fallen dieses Leidens gefunden

Diese vier 1943 operierten Ellbogengelenke wiesen hinsichtlich des linken Gelenkes ein negatives Ergebnis mit erneuter Versteifung auf Das rechte Ellbogengelenk hat bei beiden Patienten eine begrenzte Beweglichkeit von 30 behalten Alle Patienten wurden im Sauglingsalter operiert

Der dritte Fall den der Verfasser im Jahre 1930 operiert hat und der hier besprochen wird hat ein gutes dauerndes und für den Patienten sehr nützliches Resultat ergeben Das rechte Ellbogengelenk wurde bei diesem Patienten operiert da sie 4½ Monate das linke als sie 12 Monate alt war Das rechte musste 3 mal reoperiert werden zuletzt da sie 8 Jahre alt war Das Ergebnis nach 6 beziehungsweise 13 Jahren wird mittels Abbildungen und Röntgenbildern beschrieben und demonstriert

Der Verfasser bespricht die Frage ob man im Säuglingsalter wo die angenommene Inaktivitetsatrophie der vorhandenen Muskeln noch nicht so fortgeschritten ist operieren soll Oder ob man bis zum Kindesalter warten kann da die technische Ausführung der Operation leichter ist und die Nachbehandlungsumstände günstiger anliegen

Was die Inaktivitetsatrophie anbetrifft meint der Verfasser nach seinen Erfahrungen mit dem letzten Falle dass sie augenscheinlich in den für die Streck und Beugefähigkeit des Ellbogengelenkes so wichtigen dreigelenkigen Musklen nicht so rasch zunimmt Das Ergebnis mit diesem 8 Jahre alten allerdings dreimal operierten rechten Ellbogengelenk scheint zu zeigen dass es möglicherweise günstiger ist in diesem Alter zu operieren

In jedem Falle soll man die operative Behandlung der doppelseitigen ankylosis cubiti congenita selbst im vorgeschrittenen Kindesalter nicht als hoffnungslos abweisen

## REFERENCES

*Romanus R* Ein Fall von angeborener Ankylose im Ellbogengelenk Acta orthop Scandinav 4 291 1933

*Frstad H* Congenital Ankylosis of the Elbow-Joint Acta orth p Scandinav 11 296 1940

*Storen H* Two Operated Cases of Ankylosis Cubiti Congenita Acta chir Scandinav 94 65 1946

*Hoffa A* Orthopädishe Chirurgie revised b Gocht p 574 1925

né un resultat negatif avec raidissement L articulation du coude droit a chez les deux malades conserve une mobilité limitée de 30 degres Elles ont toutes ete operees a l age de nourrisson

Le troisieme cas que l auteur a opere en 1950 et qui est rapporté ici a donne un bon et durable resultat tres utile pour le malade Chez ce malade l articulation du coude droit a ete operee alors que la fillette etait agée de 4 mois et demi le coude gauche alors qu elle avait 12 mois Il a fallu reoperer le coude droit 3 fois la derniere fois lorsque la fillette etait agee de 8 ans Le resultat apres 6 et 13 ans respectivement est décrit et il en est fait la demonstration par des illustrations et des radiographies

L auteur discute la question de savoir s il convient d operer a l age de nourrisson alors que l on peut supposer que l atrophie d inactivité des muscles n est pas encore tres prononcee ou s il faut attendre que l enfant soit un peu plus age alors que l operation est techniquement plus facile a executer et que les conditions du traitement post opératoire sont plus favorables

En ce qui concerne l atrophie d inactivite l auteur pense en se basant sur les experiences du dernier cas qu elle n augmente apparemment pas tres rapidement dans les muscles des trois elements de l articulation si importante pour le pouvoir de flexion et de tension du coude Le resultat chez cet enfant de 8 ans – il est vrai reopere pour la troisieme fois dans l articulation du coude droit – semble montrer qu il est possible qu une operation a cet age soit plus favorable

Dans tous les cas il ne convient pas de rejeter le traitement chirurgical comme n ayant aucun espoir de réussite meme chez les enfants plus ages souffrant d ankylose congenitale bilaterale du coude

## ZUSAMMENFASSUNG

Die Operation der angeborenen Ankylose des Ellbogengelenkes war nicht in der Literatur besprochen als der Verfasser zwei doppelseitig operierte Falle im Jahre 1946 mitteilte (operiert 1943) Aber auch später hat der Verfasser keine Mitteilungen von operierten Fallen dieses Leidens gefunden

Diese vier 1943 operierten Ellbogengelenke wiesen hinsichtlich des linken Gelenkes ein negatives Ergebnis mit erneuter Versteifung auf Das rechte Ellbogengelenk hat bei beiden Patienten eine begrenzte Beweglichkeit von 30 behalten Alle Patienten wurden im Säuglingsalter operiert



*Fig 1*

Development of hip joint in the embryo All elements of the hip joint differentiate in situ from one mass of mesoderm (blastema) The head of the femur is globular at all times during its development Dislocation of the hip cannot occur before the opening of the joint cavity A 15 mm embryo The limb bud is well formed the femur differentiated the future femoral head and acetabulum indicated by cell condensations As yet there is no joint cavity The head is already rounded the acetabulum concave The femur is abducted and perpendicular to the acetabulum the hips stable Muscle masses are beginning to form B 30 mm embryo The acetabulum head neck and greater trochanter are well developed and the glenoid labrum overhangs the head Cortical condensations are present on the head and the acetabulum but the joint cavity is not yet open The gluteal muscles and the capsule are differentiating The head is well supported and the hip stable It is only after this stage that displacement might occur (From *Strayer L* Yale J Biol Med *16* 13 1943)

acetabulum The acetabular roof was well formed and the acetabulum of good depth and well rounded in 30 hips with complete dislocation indicating that the acetabulum could not have been at fault in these hips

Anteversion was more than 60 in only 20 per cent of the hips it was 45 or more in 58 per cent less than 45 in 42 per cent Since anteversion was not always present it could not have been the primary cause of all displacements

The capsule was elongated in every hip the only pathologic finding common to all of them and evidently the primary anatomic etiologic factor the other changes being secondary



*Fig 2*

Pathology of hip displacement specimens of *Ortolani* A Female age 2 months There was a positive jerk sign The capsule was elongated the hip moderately subluxated There was no hour glass constriction The acetabular roof and the glenoid labrum were flattened and widened from the pressure of the femoral head these are secondary changes and would regress to normal at this age with complete reduction well maintained B Male age 3 months There was a positive jerk sign The capsule was elongated permitting almost complete dislocation The acetabular roof and the labrum are quite flattened due to the high position of the head and the prolonged pressure but the head stronger because of its structure and its spherical shape is not yet deformed Probably even this much deformity would regress to normal at this age with complete reduction well maintained C Premature at 7 months 1000 gms There was no jerk sign The capsule was much elongated pulled up over the inferior portion of the acetabulum pushed up and a pocket formed around the dislocated head There was no side to-side or hour glass" constriction The acetabulum was well shaped not defective The head presses downward and inward against the labrum which thus intervenes between the head and the acetabulum There is no acetabular dysplasia despite the complete dislocation Anteversion was no factor in causing the dislocation The capsule is adherent to the ilium above the labrum the beginning of a false acetabulum The head is not deformed and in this position is likely to be freely moveable and remain spherical Complete well maintained reduction with obliteration of the superior pocket in the capsule at this age would result in a normal hip

A simple open reduction was adequate in 54 per cent of the hips all these reductions being stable indicating little or no acetabular roof defect The quality of the result did not depend on the extent of dislocation but upon the age of the infant the degree of acetabular roof deformity the amount of uncorrected anteversion and most important correction of the capsular elongation and the maintenance of good reduction

*Massie & Howorth* in 1951 reported 300 hips having open reduction fifty eight of them followed to adult life Twenty seven of the 58 hips had been well reduced and well maintained and the adult results were normal hips There was persistent subluxation in 34 hips and in adult



*Fig 3*

Dislocation of right hip boy age 14 months A With upward pressure the head is out of and completely above the acetabulum The head must move laterally before it can move upward The acetabular roof obliquity is little more than normal despite the dislocation B Same with manual traction The head comes down nearly opposite the acetabular roof In the normal hip there is no up and down movement nor telescoping Push pull films not only confirm the diagnosis but also give a clue as to whether the head can be brought down to the level of the acetabulum for reduction (From *Howorth* Textbook of Orthopaedics W B Saunders Co 1952)



*Fig 4*

A Stillbirth at term There is complete bilateral dislocation There is no deformity of the acetabular roof no dysplasia but the capsules are elongated both findings confirmed at autopsy The primary anatomic fault is in the capsule B Girl age 5 days There is moderate subluxation of each hip more on the right with slight increase in acetabular roof obliquity due to pressure of the head Each hip became normal clinically and roentgenographically following prompt reduction well maintained and has remained so for 7 years

life 85 per cent of these had an oblique acetabular roof The opposite hip in some of the cases was subluxated but untreated the subluxation persisted to adult life always with a poor result However subluxations properly treated in infancy reached adulthood with normal hips Subluxations which were not reduced gave worse results than dislocations well reduced The acetabulum developed normally if there was early



*Fig 5*

Girl age 13 months A There is slight subluxation of the left hip moderate on the right with corresponding roof obliquity due to pressure of the head against the acetabular margin An excellent result would be expected with complete reduction well maintained B Same 3 months after closed reduction incomplete or not well maintained on the right There is improvement on the right but subluxation with roof obliquity persists and the capital epiphysis is not yet ossified The left is better and ossification in the epiphysis has begun C Same 11 months after first reduction The right hip has been reduced again and well maintained The epiphysis is ossifying well but lags a bit There is very little subluxation and the roof obliquity is almost normal on each side not to be expected if there had been a primary acetabular dysplasia



*Fig 6*

A Boy age 8 months The right acetabular roof is moderately oblique with moderate upward and slight outward subluxation of the hip and pressure of the head against the acetabular margin A Frejka pillow was applied B Same age 15 months There had been improvement in the interval with treatment then treatment was stopped by the parents C Same at 23 months The subluxation persists and with pressure of the head against the outer acetabular roof the obliquity is unimproved A double plaster spica was applied for five months followed by an abduction brace with complete reduction and a normal acetabular roof

adequate reduction well maintained but if subluxation persisted the pressure of the head against the margin of the acetabulum resulted in permanent obliquity Thus the result depended upon the simple mechanical forces involved The location and degree of pressure determined the type and degree of deformity Displacement of the hip is not due to a primary defect in the acetabulum but to elongation or relaxation of the capsule



Fig 7

Girl age 21 months A There is moderate subluxation of each hip moderate acetabular roof obliquity due to pressure of the head At this age complete restoration of the acetabular roof would be expected with complete reduction well maintained B Same at age 24 months Complete reduction well maintained has resulted in just 3 months in stable hips with the formation of a normal acetabular roof This could not have occurred had there been a primary dysplasia

THE FETAL HIP

The author reported studies of *normal fetal* [illegible] 193 [illegible] 1917 between the ages of ten weeks and *full term The acetabulum* [illegible] *femoral* head and neck and capsule *were well formed even in the* [illegible] specimens The hips were all *quite stable lateral displacement being* prevented by the capsule If the *capsule were* divided the *lig* [illegible] teres would permit subluxation but not dislocation Neither [illegible] nor dislocation could occur with a normal capsule even *in* [illegible] life *Strayer*'s study indicates that displacement of the *hip* [illegible] in the embryo

HIP DISPLACEMENT IN DOGS

Twelve years ago the author found a highly *bred* [illegible] with typical congenital subluxation of both hips [illegible] common and often familial in this breed and [illegible] offering a fine experimental opportunity The [illegible] that in humans

PATHOLOGY OF SUBLUX[illegible]

Current knowledge of the pathology of [illegible] from many clinical examinations and roent[illegible] on selected cases at various ages and a [illegible]



*Fig 8*

Boy At one week of age this boy had marked general relaxation of the ligaments with marked calcaneovalgus feet but the hips were stable and in good position At 7 months external rotation of the hips was 80 internal 30 but they were stable He began to stand with support at the age of 18 months A at age 21 months the acetabular roofs were markedly oblique with bilabiation and there was dislocation on the left moderate subluxation on the right Closed reductions were done the left was unstable the right stable A double plaster spica was applied with hips in abduction worn 5 months B age 26 months Both hips were subluxated acetabular roofs oblique A brace was applied with the hips in abduction worn irregularly because of a poor situation at home C Age 31 months The left hip was again dislocated the right markedly subluxated with bilateral marked anteversion and coxa valga Open reductions were done at 33 months of age the capsule inserted with the head on the left (Colonna operation) and a shelf turned down Very good reductions were obtained A double plaster spica was worn for three and a half months followed by a brace worn irregularly D Age 43 months The acetabular roof is moderately oblique left hip markedly subluxated right moderately with marked anteversion and coxa valga Walking was begun with poor progress At 4 years old walking was fair and he had very relaxed arches and knock knees as previously The hips remained much the same except the right roof improved At 5 years old he really began to improve in his ligamentous and muscular development and his activities E Age 7½ years The left roof was fair with moderate subluxation the right good with slight subluxation and coxa valga was less There had been no vascular disturbance in the head F Same lateral views G Age 12 years There was further improvement in physical development and activity and in the hips which were quite stable but he was under average in physical activity for his age (From *Howorth* Clin orthop 29 161 1963)



*Fig 9*

Differential diagnosis The appearance of the hip subluxated from other causes is much the same in the older child or adult as subluxation of congenital or infantile origin A Subluxation with coxa plana The head is broad and flattened superiorly joint pace wide inferiorly and the roof slightly oblique secondarily The aceta bulum has not migrated B Subluxation due to spastic paralysis almost identical with congenital subluxation C Dislocation due to poliomyelitis at an early age hip nearly flail The acetabulum has filled in due to lack of pressure from the head The head is flattened medially where it presses against the acetabular margin There is coxa valga (From *Howorth & Massie* J Bone Jt Surg 33 A 171 1951)

Thirty years ago the author obtained the roentgenogram of a complete bilateral dislocation of the hip in an eight month fetus He has had two full term fetal specimens with multiple congenital deformities including bilateral dislocation of the hips Each acetabulum was shallow and flattened and the posterior and superior margins narrow The capsule was relaxed and elongated permitting 3 8 inch displacement in various directions within the capsule *Ortolani* in 1948 described 3 fetal speci mens with multiple deformities and displaced hips He stated that the pressure of the head against the posterior margin of the acetabulum had resulted in dislocation He has since obtained 13 or more fetal specimens with complete dislocation 18 with subluxation Photographs of a number of the specimens clearly reveal the relaxed capsule and the molding of the cartilage at the acetabular margin due to pressure of the head There is no evidence of "primary dysplasia of the acetabulum the entire pathology being related to the relaxed capsule and the pres sure of the head



Fig 10

A Boy age 5 years There is dislocation at and pressure against the superior margin of the acetabulum with flattening and bilabiation The base of the acetabulum has already filled in due to lack of pressure of the head There is beaking inferiorly and moderate anteversion It is too late for reduction to result in restoration of a normal acetabulum B Woman age 45 years There is persistent moderate subluxation of the right hip since infancy A new somewhat shallow acetabulum has formed at the superior margin of the acetabulum at the level of subluxation and bony overgrowth has produced a roof at this level The inferior half of the acetabulum was left behind and has partly filled in with bone probably also with cartilage and hypertrophied haversian gland The changes all conform to the effects of pressure or lack of pressure Osteoarthritis has supervened

## RELAXATION OF THE LIGAMENTS

More than 200 infants with hip displacement have been seen by the author in the past 25 years In every case there has been relaxation of the ligaments of the fingers wrists elbows and knees When they began to stand all had moderately or severely relaxed arches which persisted most of them developed knock knees often with recurvatum Relaxation of the hip joint is only part of general relaxation of the ligaments One boy is of special interest (Fig 8)

## DISCUSSION

There is adequate evidence that not all hip displacements are present at birth The word displacement includes dislocation and subluxation

and the word congenital separates those which are truly present at birth from those which occur after birth and are properly called infantile

Subluxation may persist get worse or improve depending upon the balance of mechanical forces such as muscle pull weight bearing and the effects of treatment as well as the tendency of the capsule to shorten or lengthen Dislocation rarely is reduced spontaneously and maintained but tends to get worse unless properly treated The reports of *Ortolani Coleman Caffey et al von Rosen* and others are helpful but further studies and observations of hips in the first year of life especially with reference to those which are or become displaced are desirable

Recent reports tend to confirm *Chapple*s idea that ligamentous relaxation is hormonal in origin Perhaps we shall soon have a safe and effective hormone which will be helpful in tightening relaxed ligaments

## CONCLUSIONS

The word displacement is accurate and convenient as a group term for both subluxations and dislocations The word congenital is appropriate only when it is known that displacement was present at birth The term infantile displacement is more suitable for displacements especially subluxations recognized some time after birth

Increased anteversion is not a constant finding with displacement of the hip occasionally there is retroversion Anteversion or retroversion are due to torsional stresses against the displaced femur Anteversion is not the primary cause of displacement however marked anteversion may interfere with complete reduction or favor redislocation

Acetabular deformity is not always present with hip displacement and when present is not proportional to the degree of displacement Primary dysplasia of the acetabulum is a misnomer in reference to simple displacement of the hip and is not the anatomic cause

The deformities of the acetabulum and the limbus are not primary but are due to pressure of the femoral head against the margin of the acetabulum Medial flattening and beaking of the femoral head are likewise secondary to pressure of the head against the acetabular margin

Muscle pull weight bearing or a hormonal effect may result in further stretching of the capsule The application of favorable forces leads to improvement or correction The deformities of hip displacement tend to regress if the hip is reduced early and completely an outcome not to be expected if there were a "primary dysplasia Complete correc

tion of deformity may be expected if complete reduction of the hip is maintained in a young infant

Displacement of the hip is not determined in the development of the embryo but occurs during fetal development or after birth

All the facts of displacement of the fetal or infant hip are explained by the concept of the elongated capsule and the action of purely mechanical forces No other theory is necessary to explain the facts and no other theory is consistent with the facts


## RESUME

Le mot deplacement est approprie et commode comme terme s appliquant au groupe des subluxations et des dislocations Le mot congénital n est approprie que si l on sait que le deplacement existait a la naissance Le terme deplacement infantile est plus approprie pour les deplacements en particulier les subluxations constates quelque temps apres la naissance

L anteversion accrue n est pas une trouvaille constante dans le deplacement de la hanche occasionellement il peut y avoir retroversion L anteversion et la retroversion sont dues a des forces de torsion contre le femur deplace L anteversion n est pas la cause primaire du deplacement quoi qu il en soit une anteversion marquee doit etre redressée par reduction complete ou de preference par redislocation

Une deformite du cotyle n existe pas toujours dans le deplacement de la hanche et si elle existe elle n est pas proportionnelle au degre du deplacement

Une dysplasie primaire du cotyle est un nom erroné s il est question d un simple deplacement de la hanche et n est pas une cause anatomique

Les deformites du cotyle et des limbes ne sont pas primaires mais sont dues a la pression de la tete femorale contre le bord du cotyle L aplatissement medial et le « prolongement en bec » de la tete femorale sont egalement secondaires a la pression de la tete contre le bord du cotyle

*La pression musculaire le port du poids ou un effet hormonal peuvent* provoquer une distension ulterieure de la cavite L application de forces favorables conduit a une amelioration ou a la correction Les deformites du deplacement de la hanche tendent a diminuer si la hanche est reduite tot et complement mais c est un resultat auquel il ne faut pas s attendre s il y avait une « dysplasie primaire » On peut s attendre

a la correction complete de la deformite si la reduction complete de la hanche a ete obtenue chez un jeune enfant

Le deplacement de la hanche n est pas determine dans le developpement de l embryon mais se produit durant le developpement du foetus ou apres la naissance

Toutes les circonstances du deplacement de la hanche du foetus ou de l enfant s expliquent par la conception de l elargissement de la capsul et l action de forces purement mecaniques Aucune autre theorie n est necessaire pour expliquer ces circonstances et aucune autre theorie n est compatible avec les faits

ZUSAMMENFASSUNG

Das Wort Verrenkung (displacement) ist genau und angemessen als eine Gruppenbezeichnung für sowohl Subluxationen als auch Luxationen Das Wort angeboren ist nur anwendbar wenn man weiss dass die Verrenkung bie der Geburt vorhanden war Der Ausdruck kindliche Verrenkung ist besser geeignet für Verrenkungen besonders Subluxationen die einige Zeit nach der Geburt erkannt werden

Vermehrte Anteversion ist kein konstanter Befund bei der Hüftverrenkung manchmal is eine Retroversion vorhanden Anteversion und Retroversion werden durch Drehungsbeanspruchungen auf den verrenkten Femur hervorgerufen Anteversion ist nicht die unmittelbare Ursache der Verrenkung ausgesprochene Anteversion kann jedoch eine vollkommene Einrenkung verhindern oder eine Reluxation begunstigen

Verbildung des Acetabulum ist nicht immer gleichzeitig mit einer Huftverrenkung vorhanden und wenn vorhanden nicht proportional zum Grade der Verrenkung Primäre Dysplasie des Acetabulum ist eine Fehlbezeichnung im Zusammenhang mit einer einfachen Verrenkung der Hufte und ist nicht die anatomische Ursache derselben

Die Verbildungen des Acetabulum und des Limbus sind nicht primar sondern sind die Folge des Druckes des Femurkopfes gegen den Rand des Acetabulum Mediale Abflachung und Zuspitzung des Femurkopfes sind gleichfalls als Sekundarerscheinungen wegen des Druckes des Kopfes gegen den Acetabularrand anzusehen

Muskelzug Belastung oder eine hormonale Einwirkung können eine weitere Streckung der Kapsel verursachen Die Anwendung günstig wirkender Krafte fuhrt zur Besserung oder Korrektur Die Verbildungen der Huftverrenkung haben die Neigung zurückzugehen wenn die Hüfte fruhzeitig und vollstandig eingerenkt wird ein Ausgang der nicht erwar

tet werden kann wenn es sich um eine primare Dysplasie handeln wurde Man kan eine vollstandige Korrektur der Deformitet erwarten wenn die vollstandige Einrenkung der Hufte bei einem jungen Kinde aufrechterhalten wird

Die Huftverrenkung ist nicht in der Entwicklung des Embryo bestimmt sondern entsteht während der fetalen Entwicklung oder nach der Geburt

Alle die Tatsachen der Verrenkung der fetalen oder kindlichen Hufte lassen sich mittels des Begriffes der verlangerten Kapsel und der Einwirkung von rein mechanischen Kraften erklaren Keine andere Theorie ist zur Erklarung der Tatsachen notig und keine andere Theorie entspricht den Tatsachen

## REFERENCES


*Andrén L & Borglin N E* A Disorder of Estrogen Metabolism as a Causal Factor of Congenital Dislocation of the Hip Acta orthop Scandinav *30* 169–171 1960

*Chapple A C* Congenital Dislocation of the Hip in Infancy J Pediat *6* 306 1935

*Dupuytren G* Memoire sur un deplacement original ou congenital de la tete des femurs Report gen d anat et physiol path 2 82 1826

*Farrell B P & Howorth M B* Open Reduction in Congenital Dislocation of the Hip J Bone Jt Surg *17* 35–42 1935

*Howorth M B & Smith H W* Congenital Dislocation of the Hip Treated by Open Operation J Bone Jt Surg *14* 299–313 1932

*Howorth M B* Congenital Dislocation of the Hip Ann Surg *125* 216–236 1947

*Howorth M B* The Etiology of Congenital Dislocation of the Hip Clin orthop 29 164–179 1963

*Massie W K & Howorth M B* Congenital Dislocation of the Hip J Bone Jt Surg 33 A 171–198 1951

*Massie W K* Congenital Dislocation of the Hip—Its Cause and Effects Clin orthop *8* 103–121 1956

*Ortolani M* La lussazione congenital Dell anca nuovi criteri diagnostici E profilattico correttivi Bologna Capelli 1948

*Strayer L M* Embryology of the Human Hip Joint Yale J Biol Med *16* 13–26 1943

*Wilkinson A A* Primary Factors in the Etiology of Congenital Dislocation of the Hip J Bone Jt Surg *45 B* 268–283 1963

Acta orthop. Scandinav. XXXI 225–233 1965

From the Orthopaedic Department, University of Gothenburg, Sweden
(Head: Professor Carl Hirsch, M.D.)

# STABILITY OF OSTEOSYNTHESIS IN HIP ARTHRODESIS

*By*

G. Graziati and R. Kalen

The ultimate purpose of metallic fixation for hip arthrodesis is to achieve primary stability to avoid plaster immobilization and to shorten the period of recumbency.

Various techniques have been suggested and different types of appliances have been available.

In order to determine the degree of immediate fixation that different operating procedures could produce, experiments were performed on fresh autopsy material.

Before we could systematize our experiments the problems concerning hip joint stability were analyzed in terms of factors which might influence the immediate results of osteosynthesis. In a series of orientating experiments it became obvious that the fixation obtained was at least related to the following conditions:

1. Surface contact with regard to size, shape of the joint area and diastasis.
2. Type of metallic appliance.
3. Physical properties of the bone in which the metallic fixation was inserted.

## TECHNIQUE OF EXPERIMENTS

Fresh autopsy material consisting of a hemipelvis including the hip joint and the upper part of the femur were dissected from fresh cadavers a few hours after death. The specimens were left with some soft tissue including the capsule and the ligaments of the joint. Care was taken to avoid drying of the specimens since pilot studies have shown that the physical behaviour of bone is different in dry and wet specimens.



*Fig 1*

Osteoarthritis of the hip The incongruence of the articular surfaces seen in the central portion

The pelvic portion was fixed according to the anatomical planes to a stable wooden construction by means of plastic glue (Plastic Padding) and screws in such a manner that the specimens could be handled surgically

Metallic implants of different types consisting of three flanged nails screws of different constructions pins of the Steinman type or thin nails of the Nystrom type were then applied transarticularly fixing the femoral head to the acetabulum The osteosynthetic material was applied under X ray control with surgical technique and in such a way that the joint was never opened

## SURFACE CONTACT

The contact between the surfaces was studied first by radiographs and later by anatomical measurements The latter were made after the specimens had been sectioned Adequate surface contact can only be obtained if the surfaces are congruent In joints where deformities are affecting the femoral head or the acetabulum the amount of diastasis



*Fig 2*
The three flanged nail penetrating the acetabulum forces out the femoral head causing a diastasis

will increase if the incongruent surfaces are placed in certain positions (Fig 1)

Diastatis will also occur when metallic implants are introduced through the joint This is especially true in arthrotic hips where the acetabulum is much harder than the femoral head The variations in resistance to the passage of the implant is one cause of diastasis (Fig 2)

When a nail is used diastasis increases with its size and bluntness With screws it is correlated to shape of the tip type number and distance between the threads

In order to avoid diastasis with these types of implants the material to be penetrated can be drilled To a certain extent diastasis can be decreased or partly eliminated if the femoral head is kept pressed against the acetabulum while the nail is driven in with sharp blows of the mallet

Thinner nails of the Steinmann or Nyström types have better penetrating ability and the smaller size will also cause less diastasis

Screws which are threaded only at the end will also help to avoid diastasis because they will add a compressive force between the surfaces when the threaded portion is anchored in the acetabulum

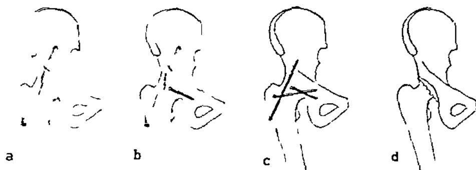



*Fig 3*
Drawings which show the four methods of arthrodesis used experimentally
a) one three flanged nail
b) one three flanged nail + one Nystrom nail
c) three Nystrom nails
d) Plastic Padding

## METALLIC APPLIANCES

Metallic implants were introduced transarticularly under X ray control without opening the capsule and ligaments when it was determined that the surfaces were in good contact First one single three flanged Smith Petersen nail was tested The nail was inserted in various controlled positions both with regard to direction and to depth in the ilium If the nail is driven in the direction of the sacro-iliac joint a maximum depth is obtained (Fig 3a)

The stability was measured in a specially constructed apparatus (Fig 4) As seen from the diagram the femoral shaft was pulled in various directions and the deflection was measured by a dial indicator with an accurancy of 1/100 mm

Diagram number 5 illustrates the amount of movement occurring when the femoral shaft is pulled in the direction of flexion abduction and adduction with a step-wise increasing force The diagram shows that the stability was less in flexion better in abduction and in adduction This is due to the fact that the axis of movement in flexion is close to that of the nail Nails introduced in the long axis of the neck into the centre of the acetabulum offer almost no stability at all because of the thinness and weakness of the acetabular floor

In order to improve stability one Nystrom nail was inserted in an antero-posterior direction Note that on the X ray drawing (Fig 3b) the Smith Petersen nail had an oblique direction while the Nystrom nail had almost a horizontal direction (60–70 of difference)

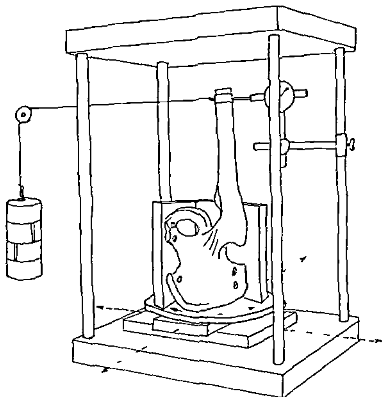


*Fig 4*
Experimental model used to test the stability of the arthrodesis

In these cases the stability improved for all tested movements (Fig 5a) Flexion was no longer possible to the same extent as when the same specimens only had a Smith Petersen nail The stability was also better in abduction and adduction Adduction was best protected but the improvement was greatest for attempted flexion

In the next series of experiments the Smith Petersen nail was removed and two Nystrom nails inserted towards the ilium and pubis (Fig 3c) The stability was now even better This was a function of the increased holding area as is shown in Fig 6

Finally in order to evaluate the amount of stability comparisons were made with the same specimens after an experimental intra articular arthrodesis was performed with plastic glue (Plastic Padding) The glue was introduced between the joint surfaces after the cartilage had been removed (Fig 3d) This type of fixation gives the maximum stability that can be obtained in an autopsy hip joint

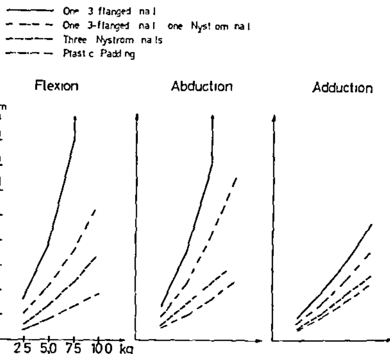



*Fig 5*

**Stress strain diagrams which show the difference in stability for the four tested methods of arthrodesis**

The curves now obtained represent the elasticity of the bone and apparatus

So far screws have not been checked for stability

In none of the experiments was plastic deformation of the osteosynthetic material noted

The amount of stability obtained with different types of osteosynthesis varies not only with the metallic implants but also with the strength and architecture of the bone The correlation between the position of the nail with regard to the bony architecture was also studied Experiments were also performed using a Smith Petersen nail first driven through one cortical layer a specific distance into cancellous bone and then tested with regard to resistance against force Subsequently it was brought through a second layer of cortical bone and the test now repeated showed increased stability (Fig 7) Furthermore the amount of bone tissue in which the nail was anchored improved the stability of the construction

It is obvious that stability depends on many variable factors in bone

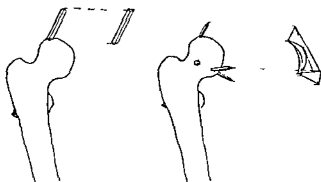


*Fig 6*
The fixed area is increased when three Nystrom nails are used

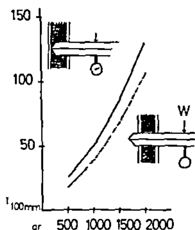



*Fig 7*
Increased stability is obtained when the nail is driven through two cortical layers

(thickness of the cortical bone degree of osteoporosis presence of bone defects cysts fractures etc )

## CONCLUSIONS

These experiments illustrate that the Smith Petersen nail in hip arthrodesis offers incomplete stability of the femur in respect to the pelvis regardless of the direction of the nail

If one Nystrom nail introduced in an antero posterior direction is added the stability is improved Three thin Nystrom nails introduced in direction of ilium pubis and ischium through the femoral neck and

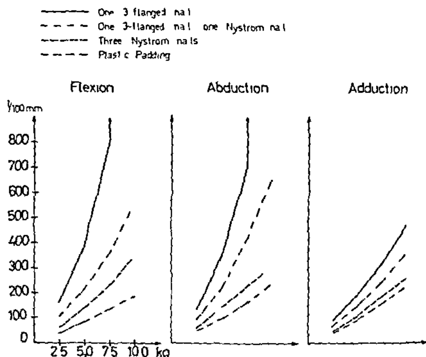



*Fig 5*

Stress strain diagrams which show the difference in stability for the four tested methods of arthrodesis

The curves now obtained represent the elasticity of the bone and apparatus

So far screws have not been checked for stability

In none of the experiments was plastic deformation of the osteosynthetic material noted

The amount of stability obtained with *different* types of osteosynthesis varies not only with the metallic implants but also with the strength and architecture of the bone The correlation between the position of the nail with regard to the bony architecture was also studied Experiments were also performed using a Smith Petersen nail first driven through one cortical layer a specific distance into cancellous bone and then tested with regard to resistance against force Subsequently it was brought through a second layer of cortical bone and the test now repeated showed increased stability (Fig 7) Furthermore the amount of bone tissue in which the nail was anchored improved the stability of the construction

It is obvious that stability depends on many variable factors in bone

*Bechtol C O & Murphy E F* The Clinical Application of Engineering Principles to the Problems of Fracture and Fracture Fixation Instructional Course Lectures The American Academy of Orthopaedic Surgery 9 272 1952

*Chapchal G* Die Arthrodese des Huftgelenkes bei der Behandlung der schweren einseitigen Arthrosis Deformans Arch orthop Unfall Chir 1942

*Compere E L Wallace I & Lee J* Material for Internal Fixation of Intracapsular Fracture of the Neck of the Femur Arch Surg 44 327 1942

*Deforest Smith A & Baab O D* A Technique for Arthrodesis of the Hip Joint J Bone Jt Surg 31 A 727 1949

*De Palma A Snedden H E & McDowell C L* Arthrodesis of the Hip with Intra medullary Fixation Clin Orthop 25 124 1962

*Harmon I H Baker D R & Reno J H* Experiments on the Holding Powers of Various Types of Metallic Internal Fixation for Transcervical Fractures of the Femur Amer J Surg 76 515 1948

*Karlen A* A Clinical Study of Arthrodesis for Arthritic Deformans of the Hip Joint Acta chir Scandinav Suppl., 1944

*Kirkaldy Willis W H Chaudhri M R & Anderson J D* Arthrodesis of the Hip with Staple Fixation J Bone Jt Surg 40 A 114 1958

*Lechten* Erfahrungen mit der interarticularen Huftarthrodese nach Kuntscher Verh dtsch orthop Ges 44 96 1957

*Lindstrom N* Partial Intra Plus Juxtaarticular Arthrodesis with Simultaneous Nailing According to Watson-Jones Acta orthop Scandinav 26 255 1957

*Mart C D* Stress Tolerance of Bone and Metal J Bone Jt Surg 33 A 827 1956

*May V R & Mauck W* Intraarticular Hip Fusion with the Intramedullary Nail Clin Orthop 25 113 1962

*McKee G K* Arthrodesis of the Hip with a Lag Screw J Bone Jt Surg 39 B 477 1957

*Newbaur J J* Arthrodesis of the Hip Produced by Internal Fixation J Bone Jt Surg 28 A 103 1946

*Nystrom G* Osteosynthesis of Medial Fractures of the Femoral Neck with the Aid of Three Nails (Multiple Nailing) Acta chir Scandinav 91 449 1944

*Stone M M* Arthrodesis of the Hip J Bone Jt Surg 38 A 1946 19 6

*Watson-Jones R & Robinson W C* Arthrodesis of the Osteoarthritic Hip Joint J Bone Jt Surg 38 B 353 1956

*Venable C S & Stuck W G* Results of Recent Studies and Experiments Concerning Metals Used in the Internal Fixation of Fractures J Bone Jt Surg 30 A 247 1948

*Vermstein* Erfahrungen bei Huftarthrodese Verh dtsch orthop Ges 44 93 1956

Acta orthop Scandinav XXXI 234-256 1965

From the Orthopaedic Clinic Lund Sweden
(Head Prof Gunnar Wiberg)

# PES PLANO VALGUS STATICUS JUVENILIS AND ITS OPERATIVE TREATMENT

*By*

STEFÁN HARALDSSON

Pes plano valgus staticus juvenilis designates the growing foot that shows the typical distortions when loaded but is of normal clinical and roentgenological appearance when unloaded—at least in the early stage of the condition

It is the commonest type of pes plano valgus and the commonest deformity of the foot Owing to this frequency of the disease and the secondary pathological changes occurring later in life the condition often represents a considerable medical and social problem

The primary cause of the deformity is still obscure Most authors believe it to be a disproportion between the strength of the muscles and ligaments of the feet and the weight to be carried (*Bardenheuer* 1910 *Brinkmann* 1939 *Milch* 1942) Since the condition is so common some authors believe it might be due to constitutional weakness of these structures (*Miller* 1927 *Hohmann* 1951 and others) This line of thought is supported by the familial occurrence of the disease which was also seen in the present material (*vide infra*)

*Niederecker* (1950 1959) stressed the role of muscle anomalies in the causation of the condition and discusses a statically unfavourable insertion of the musc tibialis anterior and musc peroneus tertius as well as the occurrence of a musc peroneus quartus Other authors such as *Hoke* (1931) suggest the possibility of muscle incoordination as an etiological factor *Timmer* (1924) *Erlacher* (1942) believe the cause to be a congenital pes calcaneo valgus *Weckenstein* (1960) expresses a similar line of thought *Bohm* (1930) suggests inhibition of the normal development of the ankle joint, *Harris & Beath* (1948) speak of congenital anomaly of talus and calcaneus while *Stracker* (1953) believes neurogenic factors to be responsible *Kidner* (1929)

pointed out that prehallux may play a role in this connection *Priester* (1958) suggests endocrine disorders.—Opinions on the primary cause of the condition thus vary widely but fall largely within 2 main groups namely a constitutional weakness of the ligaments and muscles and secondly a congenital developmental disorder.

The divergence of opinions of the cause of the disease has resulted in difference of opinion concerning adequate treatment. Most cases respond to conservative treatment during childhood and adolescence. *Schaffer* (1951) *Hackenbroch* (1961) even believe that in some cases the foot becomes normal even without treatment. Many cases are treated with foot supports and exercise of the foot muscles. Some authors claim that the use of a support is nonphysiological and recommend foot exercises only (*Nordenfelt* 1942).

In some cases however the condition is refractory to even prolonged conservative treatment. It is in these cases that surgery may be considered. It is true that some authors are reluctant to operate upon the growing static plano-valgus foot. It is however known that this abnormal loading of the foot with pathological displacement of the foot bones will if untreated result in structural changes of the skeleton and soft tissues with fixation of the distortion and increasing symptoms. Various authors therefore believe operation to be indicated in cases not responsive to long conservative treatment (*Hohmann* 1931 1951 *Lange* 1951 *Erlacher* 1955 *Niederecker* 1959 *Hackenbroch* 1961 and others). Most of these operations are to be regarded as prophylactic and performed in order to facilitate further normal development of the foot. The primary indication for operation of these feet is never cosmetic.

The operations for pes plano-valgus staticus juvenilis fall into 3 groups namely 1) intervention on the ligaments 2) on the tendons 3) on the bones. Even combinations of all 3 types have been described.

Of the first group mention might be made of *Hohmann*'s (1931) method with reinforcement of ligaments on the medial side of the tarsus a similar operation is recommended by *Milch* (1942).

The purpose of the operations on the tendons is mainly to strengthen the supinating components of the foot in relation to the pronating and to raise the medial longitudinal arch. *Gocht* (1905) medialized the insertion of the Achilles tendon. *Hubscher* (1910) shortened the flexor hallucis longus tendon to which he sewed part of the tibialis posterior tendon. A widely used tendon operation is transposition of the insertion of the tibialis anterior tendon to os naviculare an operation first

described by *Muller* (1903) and since by *Young* (1939) *Dinklage* (1950) *Schaffer* (1951) *Breitenfelder* (1953) and others *Niederecker* (1932 1959) and *Penners* (1959) transposed the tibialis anterior and medialized the peroneus tertius

Of operations on bones with or without intervention on soft tissues in the growing static plano valgus foot arthrodesis of different joints at the vertex of the medial longitudinal arch (*Miller* 1927 *Schede* 1929 *Hoke* 1931) and arthrodesis of the talocalcaneous joints (*Leavitt* 1943) deserve mentioning

Arthrodesis is however less suitable because like osteotomy it may disturb the further growth of the young foot On the other hand it has been stressed by other workers in this field that operations on the soft tissues only are insufficient in severe cases (*Hoffmann-Kuhnt* 1950 *Hackenbroch* 1961)

The ideal operation would therefore be one that prevents pathological displacement without interfering unnecessarily with the resilience of the young foot and the growth of its bones but which nevertheless makes the foot stable enough to prevent recurrences *Chambers* (1946) tried to prevent displacement between the talus and calcaneus by lifting the lateral part of the facies articularis post of the calcaneus a measure which *Grice* (1952) believed to be insufficient in severe valgus

*Grice* (1952 1955) performed extra articular talocalcaneal arthrodesis but his series consisted of pes plano valgus paralyticus only *Picard & Vimran* (1961) who used *Grice*s method had no cases of static plano valgus feet in in their material either

It is clear from the literature that opinions differ as to the most suitable age for the operation of the condition Of the authors who prefer operations on the soft tissues *Young* (1939) did not operate until the children were 10 years of age *Milch* (1942) between 8–15 years *Dinklage* (1950) preferably between 6–7 years *Breitenfelder* (1953) between 11 and 15 years *Niederecker* (1959) from the end of the fifth year *Penners* (1959) from 6–12 years As to treatment with operation on the bones average age of the patients in *Miller*s (1927) material was 12 years and *Hoke* (1931) was reluctant to operate upon children below 8 years

## AUTHOR S SERIES

During 1954–1961 we operated upon 54 growing feet for static plano-valgus at the Orthopaedic Clinic Lund All of these cases had failed to

respond to conservative treatment and some cases showed signs of progression despite treatment The operation is regarded as prophylactic performed to prevent later organic deformities None of the cases were operated upon for cosmetic reasons

## METHODS

The purpose of the standard method is to correct and prevent pronation abduction position of the loaded calcaneus which the author believes to be the primary cause of the other distortions A bone block is placed in the tarsal sinus to prevent pronation abduction of that part of the foot under the talus The method is largely that described by *Grice* (1952 1955) He aimed to produce extra osseous talocalcaneal arthrodesis by autogenous bone grafts His material consisted entirely of feet with paralytical plano valgus In the present material talocalcaneal arthrorisis was produced b the insertion of homogenous grafts from the bone bank

The tarsal sinus is exposed from the lateral aspect of the foot The soft tissues are removed from the sinus in to the ligamentum interosseum The surface of the calcaneus is scarified Homogenous cortical bone is shaped into wedges The calcaneus is placed in supination plantar flexion and adduction At the same time an attempt is made to force the calcaneus ventrally under the talus The wedges are placed in the tarsal sinus with the base laterally and the proximal end dorsally in relation to the distal end (Fig 1)

Inserted in this way the wedges are almost perpendicular to the axis of motion of the subtalar joints and are locked in position when the heel is placed in mid position in which it is afterwards fixed in plaster (*Grice* 1955)

In 24 of the feet the operation on the bones was extended to include transposition of the insertion of the tendon of the tibialis anterior to the os naviculare The line of pull of this muscle passes through the axis of motion of the talotarsal




*Fig 1*
Position of bone grafts (Foot No 54)

described by *Muller* (1903) and since by *Young* (1939) *Dinklage* (1950) *Schäffer* (1951) *Breitenfelder* (1953) and others *Niederecker* (1932 1959) and *Penners* (1959) transposed the tibialis anterior and medialized the peroneus tertius

Of operations on bones with or without intervention on soft tissues in the growing static plano valgus foot arthrodesis of different joints at the vertex of the medial longitudinal arch (*Miller* 1927 *Schede* 1929 *Hoke* 1931) and arthrodesis of the talocalcaneous joints (*Leavitt* 1943) deserve mentioning

Arthrodesis is however less suitable because like osteotomy it may disturb the further growth of the young foot On the other hand it has been stressed by other workers in this field that operations on the soft tissues only are insufficient in severe cases (*Hoffmann-Kuhnt* 1950 *Hackenbroch* 1961)

The ideal operation would therefore be one that prevents pathological displacement without interfering unnecessarily with the resilience of the young foot and the growth of its bones but which nevertheless makes the foot stable enough to prevent recurrences *Chambers* (1946) tried to prevent displacement between the talus and calcaneus by lifting the lateral part of the facies articularis post of the calcaneus a measure which *Grice* (1952) believed to be insufficient in severe valgus

*Grice* (1952 1955) performed extra articular talocalcaneal arthrodesis but his series consisted of pes plano valgus paralyticus only *Picard & Mimran* (1961) who used *Grice*s method had no cases of static plano-valgus feet in in their material either

It is clear from the literature that opinions differ as to the most suitable age for the operation of the condition Of the authors who prefer operations on the soft tissues *Young* (1939) did not operate until the children were 10 years of age *Milch* (1942) between 8-15 years *Dinklage* (1950) preferably between 6–7 years *Breitenfelder* (1953) between 11 and 15 years *Niederecker* (1959) from the end of the fifth year *Penners* (1959) from 6–12 years As to treatment with operation on the bones average age of the patients in *Miller*s (1927) material was 12 years and *Hoke* (1931) was reluctant to operate upon children below 8 years

## AUTHOR S SERIES

During 1954–1961 we operated upon 54 growing feet for static plano-valgus at the Orthopaedic Clinic Lund All of these cases had failed to

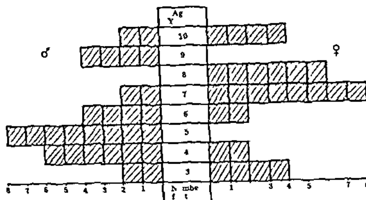



*Fig 3*
Age at operation Sex incidence

was considered The duration of this pre operative treatment was 4 years on the average

The patients ages at the time of operation varied between 3 years 9 months and 10 years 10 months The mean age was 6 3 years 28 of the feet belonged to boys 26 to girls (Fig 3)

Thirty (55 5 per cent) of the feet caused local symptoms before operation 22 of the feet were painful when loaded in 8 feet there were symptoms from the feet as well as from the lower legs

In ? feet (48 1 per cent) one or more of the other members of the family were described as having a similar condition

In all of the cases the condition was bilateral as were all of the operations

None of the patients had had any previous disease of interest

## AFTER EXAMINATION—RESULTS

All of the feet were after examined The interval between the operation and the after examination was 4 months to 7 years This interval was 1 year or more for 50 feet more than 2 years for 34 (Fig 4)

The patients ages at the time of the after examination varied between 5 years and 14 years 8 months 24 of the feet were above 10 years at the time of the after examination At the after examination the feet were studied clinically roentgenologically photographically and pedographically

The position of the loaded heel was studied in the way illustrated in Fig 5 The vertical longitudinal axis of the heel was determined by the method of *Lan & Wachsmuth* (1935)

Roentgenograms were taken of the loaded foot Measurements were made of the angle in the roentgenogram which the longitudinal axis

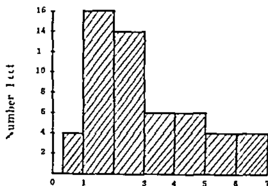



*Fig 4*
Duration of observation (Years)

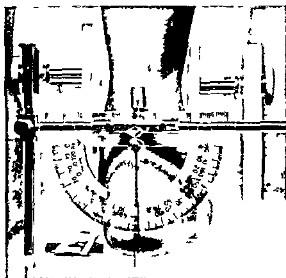


*Fig 5*
Method of measuring pronation of heel

of the talus formed with the floor (TF angle) Tomograms in the frontal plane were taken of the calcaneus to evaluate its position when the foot was loaded

*Freiberg*s method of pedography was used

Of 30 feet that had caused symptoms before operation (*vide supra*) 21 were now symptom free Six feet were still sometimes painful but less than before the operation One foot was more painful while 2 had been operated too recently to permit evaluation

In 48 feet the valgus position of the loaded heel was 5 or less which

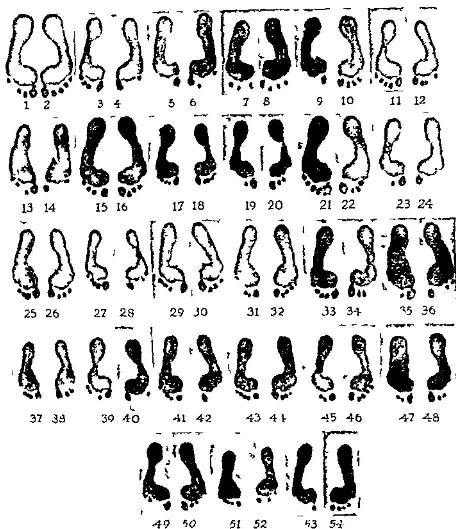



*Fig 6*

Pedographs of operated feet at review

may be regarded as normal (*Lang & Wachsmuth* 1935) In 3 feet 10–15° valgus was found and in 3 slight varus

In 51 feet the depression of the loaded medial longitudinal arch was less marked than before operation In 42 of these the curvature of this arch was judged as normal (Fig 6) In 3 feet the arch was still completely depressed when loaded (*Feet 13 35 47 (Fig 6)*) in 9 it was still partially depressed (Feet 14 25 26 36 37 38 48 51 52 (Fig 6))

TABLE 1

*Pes Plano Valgus Staticus Juvenilis Results of 54 Operated Feet*

| Foot no | Type of operation | Result | Foot no | Type of operation | Result |
|---|---|---|---|---|---|
| 1 | 1 + 2 | +++ | 28 | 1 + 2 | +++ |
| 2 | 1 + 2 | +++ | 29 | 1 + 2 | +++ |
| 3 | 1 + 2 | +++ | 30 | 1 + 2 | +++ |
| 4 | 1 + 2 | +++ | 31 | 1 | +++ |
| 5 | 1 | +++ | 32 | 1 | +++ |
| 6 | 1 | ++ | 33 | 1 | +++ |
| 7 | 1 + 2 | +++ | 34 | 1 | +++ |
| 8 | 1 + 2 | +++ | 35 | 1 | + |
| 9 | 1 | + | 36 | 1 | ++ |
| 10 | 1 | +++ | 37 | 1 + 2 | ++ |
| 11 | 1 | +++ | 38 | 1 + 2 | ++ |
| 12 | 1 | +++ | 39 | 1 | +++ |
| 13 | 1 | + | 40 | 1 | +++ |
| 14 | 1 | ++ | 41 | 1 | +++ |
| 15 | 1 | +++ | 42 | 1 | +++ |
| 16 | 1 | +++ | 43 | 1 + 2 | +++ |
| 17 | 1 | +++ | 44 | 1 + 2 | +++ |
| 18 | 1 | +++ | 45 | 1 | +++ |
| 19 | 1 | +++ | 46 | 1 | +++ |
| 20 | 1 | +++ | 47 | 1 + 2 | + |
| 21 | 1 + 2 | +++ | 48 | 1 + 2 | ++ |
| 22 | 1 + 2 | +++ | 49 | 1 + 2 | +++ |
| 23 | 1 | +++ | 50 | 1 + 2 | +++ |
| 24 | 1 | +++ | 51 | 1 + 2 | ++ |
| 25 | 1 | ++ | 52 | 1 + 2 | ++ |
| 26 | 1 | ++ | 53 | 1 + 2 | +++ |
| 27 | 1 + 2 | +++ | 54 | 1 + 2 | +++ |

1 = Bone block operation
2 = Tendon transference
1 + 2 = Combined operation
+++ = Good
++ = Improved
+ = Poor

TOTAL

| | | | |
|---|---|---|---|
| Good | 40 | 22<br>18 | Bone block op<br>Combined |
| Improved | 10 | 5<br>5 | Bone block op<br>Combined |
| Poor | 4 | 3<br>1 | Bone block op<br>Combined |

As mentioned the subluxation of the talus and the depression of the medial longitudinal arch of the foot are judged also by the TF angle In the 42 feet with a normal medial longitudinal arch the mean TF angle was 22 In the 9 feet that showed partial depression of the arch at the after examination the angle was on the average 30 In the feet with a total depression of the arch the average TF angle was 36

The functional results were classified according to whether the children took part in school gymnastics or not Regarding 36 feet the answer was in the affirmative regarding 6 the children were still below school age and 2 of the feet had been operated upon too recently to permit evaluation of the functional results of the operation Ten feet were such as to exempt the children from school gymnastics

The after examination showed that in 5 of the feet the bone graft had been absorbed In one of these feet the loaded heel showed 10 valgus and the medial longitudinal arch was low The medial longitudinal arch was completely depressed in one and partly in another The remaining 2 feet were of normal physical and roentgenological appearance when loaded 5 years 6 months and 4 years 9 months respectively after the operation

The after examination showed that in addition to the desired prevention of pronation abduction supination of the talocalcaneal joints had disappeared from 7 feet In these cases then the operation had produced talocalcaneal arthrodesis ad modum *Grice* (1952 1955)

Table 1 summarizes the results as judged by the after examination The following criteria were used for the loaded foot

*Good* Normal medial longitudinal arch 5 valgus or less of heel No symptoms or less accentuated *Improved* Partial normalization of medial longitudinal arch 5 –10 valgus of heel Symptoms unchanged *Poor* Total depression of medial longitudinal arch More than 10 valgus of heel Symptoms increased

It is clear from Table 1 that the results obtained in 4 feet were regarded as poor In one the bone graft had been completely absorbed 4 years 5 months after operation In one the heel was in slight varus position with increased symptoms Regarding one foot the patient had not complied with instructions given and used the supports for only 4 months

## DEMONSTRATION OF CASES

Feet Nos 27 and 28 Figs 7 8 9 10 Operation at 4 years 4 months with arthrorisis and transposition of tendon Fig 7 The loaded com

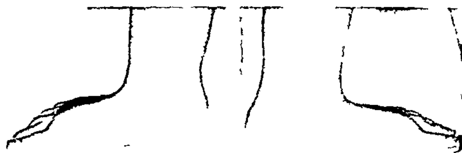


*Fig 7*
Foot No 27 (r) and 28 (l) Before operation

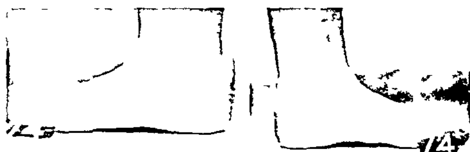


*Fig 8*
Foot No 27 (r) and 28 (l) At review



*Fig 9* *Fig 10*
*Fig 9* Foot No 27 (r) and 28 (l) At review
*Fig 10* Foot No 27 (r) and 28 (l) Pedograph at review

*Fig 11*
Foot No 11 (r) and 12 (l) Before operation
*Fig 12*
Foot No 11 (r) and 12 (l) At review



*Fig 13*
Foot No 11 (r) and 12 (l) Before operation

pletely depressed medial longitudinal arches Figs 8 9 10 were taken at after examination 2 years 8 months after operation The medial longitudinal arches are reconstructed (Fig 8) the loaded heels assume an almost normal position (Fig 9) and the pedograph is normal (Fig 10)

Feet Nos 11 and 12 Figs 11 12 13 14 15 16 17 Operation at 4 years 6 months Arthrorisis only Fig 11 Depression of longitudinal arches before operation Fig 12 The same feet 4 years 8 months after operation Fig 13 Pre-operative roentgenograms of the loaded feet




*Fig 14*
Foot No 11 (r) and 12 (l) At review



*Fig 15*
Foot No 11 (r) and 12 (l) Before operation





*Fig 16* *Fig 17*

*Fig 16* Foot No 11 (r) and 12 (l) At review
*Fig 17* Foot No 11 (r) and 12 (l) Pedographs at review

The TF angle is 40 on the right side and 45 on the left At the after examination (Fig 14) the TF angles are 30 and 22 respectively Fig 15 The pre-operative valgus of the loaded heels Fig 16 Post operatively the heels are in midposition Fig 17 The normal post operative pedograph

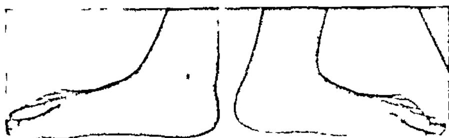


*Fig 18*
Foot No 29 (r) and 30 (l) Before operation

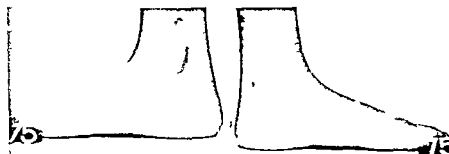


*Fig 19*
Foot No 29 (r) and 30 (l) At review




*Fig 20*
Foot No 29 (r) and 30 (l) Before operation

Feet 29 and 30 Figs 18 19 20 21 22 23 Operation at 6 years 4 months Combined operation Before operation the loaded medial longitudinal arches are depressed (Fig 18) At after examination 2 years 3 months after the operation the arches are reconstructed (Fig 19) Figs 20 21 illustrate the skeleton of the loaded foot The TF angle before operation (Fig 20) was 35 on the right side and 42 on the left




*Fig 21*
Foot No 29 (r) and 30 (l) At review



*Fig 22*



*Fig 23*

*Fig 22* Foot No 29 (r) and 30 (l) At review
*Fig 23* Foot No 29 (r) and 30 (l) Pedographs at review

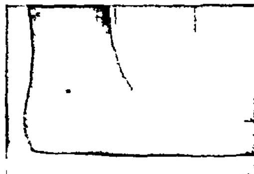


*Fig 24*



*Fig 25*



*Fig 26*

Foot No 54 with pedograph Before operation

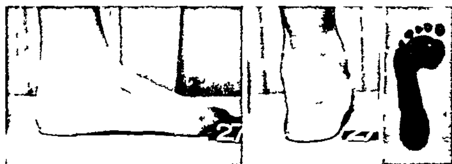


*Fig* 27 *Fig* 28 *Fig* 29

Foot No 54 with pedograph At review
(Postoperative roentgenogram of foot No 54 see Fig 1)

At the after examination the angles were 25 and 22 respectively (Fig 21) Fig 22 Normal position of the heel at after examination and Fig 23 Normal pedograph at the same time

Foot 54 Figs 24 25 26 27 28 29 Operation at 10 years 4 months Combined operation Fig 24 The completely depressed loaded longitudinal arch before operation which is also apparent from the pedograph in Fig 26 Fig 25 Pronounced valgus position of the calcaneus before operation Figs 27 28 and 29 were taken 4 months after the operation The medial longitudinal arch is now reconstructed (Fig 27) The heel is loaded in midposition (Fig 28) and the pedograph is normal (Fig 29)

## DISCUSSION

Though most cases of pes plano valgus staticus juvenilis respond to conservative treatment some are refractory Judging from the literature there is now an increasing tendency to treat these cases surgically to prevent later permanent deformities

Intervention on the soft tissues alone is regarded by many authors as insufficient for severe cases Osteotomy and arthrodesis of the growing foot bones which consist partly of cartilage are believed to be unsuitable because it may interfere with the normal growth of the skeleton

As for the symptoms in children with pes plano-valgus staticus it is widely believed that most cases are symptom free In the present material 30 (55 5 per cent) of 54 feet produced symptoms The material was however selected It might however be stressed that in *Bren*

*ning*'s (1960) series of 58 children with flatfoot (mostly 6-7 years of age) almost half had symptoms.

In the present material the results of operation were not found to vary with the age of the patients. Since operation is only indicated in cases refractory to long conservative treatment, operation is not regarded as indicated in children below 4 years. No incorrigible skeletal deformities develop below this age. On the other hand operation should be performed early enough to secure normal later development of the growing bones of the foot and before the deformity becomes irreversible. Operation before the age of 12 is therefore indicated. After this age the foot becomes structurally more compact and then there is a greater risk that it will no longer be possible to correct the distortions.

*In 7 of the feet the after examination showed not only impaired pronation* but also impaired supination. One of these feet showed slight varus, the others could be loaded without deformation. Since it is however desirable to interfere as little as possible with the normal function of the foot, attempts should be made to avoid such an unnecessary elimination of supination partly by not scarifying the lower surface of the talus, partly by interposition of soft tissue between the proximal end of the transplant and the talus. Fixation of the distal end of the graft to the calcaneus is the only fixation that should be aimed at.

In 42 feet in which the longitudinal arch was judged as being normal when loaded the average TF angle was 22. This is in accord with *Niederecker*'s (1959) finding of an average angle of 23 in normals.

Twenty-four of the feet belong to patients who at the time of the after examination were above *10 years, the oldest was barely 15 years*. Roentgen or clinical examination revealed nothing to suggest that the operation had disturbed growth of any of the feet.

The results of operation were judged as good for 40 feet (74.1 per cent), improved for 10 (18.5 per cent) and poor for 4 (7.4 per cent) (Table 1).

*The after examination revealed no certain difference* between the results obtained in those feet submitted to arthrorisis alone and those in which the operation was extended to include transposition of the tendon (Table 1). In order to keep traumatization to a minimum it would therefore appear that talocalcaneal arthrorisis with homogenous bone transplant alone is satisfactory in the treatment of this type of pes plano-valgus. It affects only the pronation-abduction of the foot. Its spares the growing foot because it is extra-articular and extra-

osseous It aims at normalizing the inter relationship between the foot bones when the foot is loaded and thus contributes to a more physio logical development of the bones muscles and ligaments of the static juvenile plano valgus foot

SUMMARY

1 Pes plano valgus staticus juvenilis is the commonest deformity of the foot In the beginning it is a static deformity which leads to organic pathological changes

2 The primary cause of the disease is not known with certainty but it is widely believed that a disproportion exists between the weight to be carried and the development of the muscles and ligaments

3 Most feet of this type are improved by conservative treatment Some however are refractory to such therapy There is an increasing tendency to operate upon such refractory cases to enable subsequent normal development of the foot

4 The material consisted of 54 feet with plano valgus staticus juvenilis refractory to conservative treatment The duration of con servative treatment before operation was 4 years on the average The patients ages at the time of operation were barely 4 years to barely 11 years with a mean age of 6 3 years 28 feet belonged to boys 26 to girls

5 Operative methods Arthrorisis talocalcanea with insertion of homogenous transplant from the bone bank into the tarsal sinus The bone block prevents pronation abduction of the foot plate below the talus In 24 feet the operation on the bones was extended to include transposition to the os naviculare of the insertion of the tibialis an terior tendon The transposition increases the supinating and arch lifting effect of the muscle

6 The interval between operation and the after examination varied between 4 months and 7 years It was 1 year or more for 50 feet and more than 2 years for 34 The age at the time of the after examination ranged from 5 years to almost 15 years with 24 feet above 10 years

7 At the after examination the feet were studied clinically and roentgenologically (with measurement of the TF angle and tomo- graphy of the calcaneus) photographically and pedographically Of 30 feet which had had symptoms before the operation 21 were symptom free at the after examination The results of the operation were judged as good for 40 feet (74 1 per cent) improved for 10 (18 5 per cent) and poor for 4 (7 4 per cent)

8 The results of operation were not found to vary with age of the patients The most suitable age for operation appears to be between 4 and 12 years

9 Clinical and roentgenological examination revealed nothing suggesting that the operation had caused disorders of growth

10 No difference was found with certainty between the results obtained in feet operated upon with arthrorisis alone and those in which the operation was extended to include transposition of the tendon

Arthrorisis talocalcanea performed with homogenous graft from the bone bank is regarded as a satisfactory operation for pes plano valgus staticus juvenilis not responding to conservative treatment

## RESUME

1 Le pied plat valgus statique chez les enfants est la déformité du pied la plus commune Au début c est une deformite statique qui conduit a des alterations pathologiques organiques

2 On ne connait pas avec certitude la cause primaire de la maladie mais on croit generalement qu il existe une disproportion entre le poids a supporter et le developpement des muscles et des ligaments

3 La plupart des pieds de ce type s ameliorent a la suite d un traitement conservateur Certains sont cependant refractaires a cette thérapie On a de plus en plus tendance a operer ces cas réfractaires afin de permettre par la suite un developpement normal du pied

4 Le materiel d observation étudie ici comprend 54 pieds plats valgus statiques chez les enfants refractaires au traitement conservateur La durée du traitement conservateur avant l operation avait ete de 4 ans en moyenne L age des malades au moment de l opération a varie entre 4 et 11 ans avec un âge moyen de 6 3 ans 28 pieds appartenant a des garçons 26 a des filles

5 Methode d opération arthrorisis talocalcanea avec insertion de transplantation homogene de la banque des os dans le sinus tarsal Le bloc osseux empeche la pronation abduction de la plante du pied au dessous du tarse Dans 24 pieds l operation des os a comporte également la transposition a l os naviculaire de l insertion du tendon tibial anterieur La transposition accroit l effet de supination et d élévation de la voute opére par le muscle

6 L intervalle entre l operation et l examen complementaire a varié entre 4 mois et 7 ans Il a ete d un an ou plus pour 50 pieds et de plus

de 2 ans pour 34 L âge à l époque du reexamen a varie entre 5 et 15 ans et a ete de plus de 10 ans pour 24 pieds

7 Au reexamen les pieds ont ete etudies cliniquement et radiologiquement (avec la mensuration de l angle TF et tomographie du calcaneum) photographiquement et pedographicalement Sur 30 pieds presentant des symptomes avant l operation 21 etaient libres de symptomes au moment du reexamen Les resultats de l operation ont été juges bons pour 40 pieds (74 1 pour cent) ameliores pour 10 (18 5 pour cent) et mediocres pour 4 (7 4 pour cent)

8 Les resultats de l operation n ont pas varie avec l age des malades Le meilleur age pour l operation semble etre entre 4 et 12 ans

9 L examen clinique et radiologique n a rien decelé qui puisse laisser supposer que l operation ait produit des troubles de la croissance

10 Il n a pas ete trouve de difference certaine dans les resultats obtenus pour les pieds operes par arthrorisis seule et ceux dans lesquels l operation a comporte aussi la transposition du tendon

L arthrorisis talocalcanea executee avec greffe homogene de la banque des os est consideree une operation satisfaisante pour le pied plat valgus statique chez l enfant ne reagissant pas au traitement conservateur

## ZUSAMMENFASSUNG

1 Pes planovalgus staticus juvenilis ist die häufigste Verbildung des Fusses Im Beginn ist er eine statische Deformitet die zu organischen pathologischen Veranderungen führt

2 Die ursprungliche Ursache der Erkrankung ist nicht mit Sicherheit bekannt aber man nimmt weithin an dass es sich um ein Missverhaltnis zwischen dem zu tragenden Gewicht und der Entwicklung der Muskeln und Bander handelt

3 Die meisten derartigen Fusse werden durch konservative Behandlung gebessert Einige jedoch lassen sich durch eine derartige Behandlung nicht beeinflussen Es besteht eine zunehmende Neigung derartige widerspenstige Falle zu operieren um eine folgende normale Entwicklung des Fusses zu ermoglichen

4 Das Material besteht aus 54 Fussen mit pes planovalgus staticus juvenilis die einer konservativen Behandlung Widerstand leisteten Die Dauer der konservativen Behandlung vor der Operation was durchschnittlich 4 Jahre Das Alter der Patienten zur Zeit der Operation

war 4 bis 11 Jahre mit einem Durchschnittsalter von 6 3 Jahren Es handelte sich um 28 Knaben und 26 Mädchenfusse

5 Operative Methoden Arthrorisis talocalcanea mit Einfugung eines homogenen Transplantates von der Knochenbank in den tarsalen Sinus Der Knochenblock verhindert Pronation Abduktion der Fussplatte unterhalb des Talus In 24 Fussen wurde die Operation an den Knochen durch die Einbeziehung einer Transposition des Ansatzes der Sehne des m tibialis anterior auf das os naviculare erweitert Die Verpflanzung erhoht die supinatorische und Fussgewolbe erhohende Wirkung des Muskels

6 Der Zeitraum zwischen der Operation und der Nachuntersuchung schwankte zwischen 4 Monaten und 7 Jahren Er war 1 Jahr oder mehr in 50 Fussen und mehr als 2 Jahre in 34 Das Alter zur Zeit der Nachuntersuchung reichte von 5 bis nahezu 15 Jahren 24 Fusse waren alter als 10 Jahre

7 Bei der Nachuntersuchung wurden die Fusse klinisch und rontgenologisch (mittels Messung des TF Winkels und Tomographie des Calcaneus) fernerhin fotographisch und pedographisch studiert Von 30 Fussen die vor der Operation Symptome aufwiesen waren 21 symptomfrei bei der Nachuntersuchung Die Ergebnisse der Operation wurden in 40 Füssen (74 1 Prozent) als gut angesehen 10 (18 5 Prozent) wiesen eine Besserung auf und 4 (7 4 Prozent) hatten ein schlechtes Resultat

8 Die Ergebnisse der Operation waren nicht vom Alter des Patientens abhangig Das geeignetste Operationsalter scheint das zwischen 4 und 12 Jahren zu sein

9 Klinische und rontgenologische Untersuchung enthullte nichts das als eine Wachstumsstorung als Operationsfolge zu deuten ware

10 Es wurde kein sicherer Unterschied zwischen den Ergebnissen bei Fussen die mit alleiniger Arthrorisis oder mit der erweiterten die Sehnentransposition umfassenden Operation behandelt wurden gefunden

Arthrorisis talocalcanea mit einem homogenen Spahn von einer Knochenbank ausgeführt wird als eine zufriedenstellende Operation in Fällen von pes planovalgus staticus juvenilis die auf konservative Behandlung nicht ansprechen angesehen

## REFERENCES

*Bardenheuer B* Der statische Pes valgus und valgoplanus seine Ursache seine Folgen und seine Behandlung Z orthop Chir 96 1–147 1910

*Breitenfelder H* Zur operativen Behandlung des Knickplattfusses Jugendlicher Chirurg 24 311 314 1953

*Brenning R* "Vattvark och plattfotter Svenska Lakartidn 57 3646–3648 1960

*Brinkmann E* Entstehung und Behandlung der Fussinsufficienz im Kindes und Erwachsenalter Arch klin Chir 196 590–598 1939

*Böhm M* Pes valgus staticus Z orthop Chir 52 424–452 1930

*Chambers E F S* An Operation for the Correction of Flexible Flat Feet of Adolescents West J Surg 54 77–86 1946

*Dinklage D* Die Muskeltransplantation als Therapie des Pes Valgus Inaugural Dissertation Humbolt Universitat Berlin 1950

*Erlacher P* Der angeborene Hackenfuss die Ursache des kindlichen Knickplattfusses Wien klin Wschr 55 1002–1003 1942

*Erlacher P* Lehrbuch der praktischen Orthopadie W Maudrich Wien–Bonn 1955

*Freiberg* (quoted by *Hohmann G* 1951)

*Gocht H* Sehnenoperation beim Pes plano-valgus Z orthop Chir 14 693–697 1905

*Grice D S* An Extra articular Arthrodesis of the Subastragalar Joint for Correction of Paralytic Flat Feet in Children J Bone Jt Surg 34–A 927 940 1952

*Grice D S* Further Experience with Extra articular Arthrodesis of the Subtalar Joint J Bone Jt Surg 37–A 246–259 1955

*Hackenbroch M* Der Plattfuss in *Hohmann G Hackenbroch M & Lindemann K* Handbuch der Orthopadie G Thieme Stuttgart 1961

*Haraldsson S* Operative Treatment of Pes Plano valgus Staticus Juvenilis Annual meeting of the Section of Orthopaedics Svensk Ortopedisk Forening held on Dec 9 1961 Stockholm

*Haraldsson S* Operative Treatment of Pes Plano-valgus Staticus Juvenilis Preliminary Communication Acta orthop Scandinav 32 492–498 1962

*Haraldsson S* Pes plano-valgus Svenska Lakartidn 60 2687–2705 1963

*Harris R I & Beath T* Hypermobile Flat foot with Short Tendo Achillis J Bone Jt Surg 30–A 116–138 1948

*Hellman Kuhnt H* Der Tibialis anticus beim Plattfuss und beim Hohlfuss Z Orthop 79 519 521 1950

*Hohmann G* Zur operativen Plattfussbehandlung Chirurg 2 593–595 1931

*Hohmann G* Fuss und Bein J F Bergmann Munchen 1951

*Hoke M* An Operation for the Correction of Extremely Relaxed Flat Feet J Bone Jt Surg 13 773–783 1931

*Hübscher C* Der operative Verstarkung des Flexor hallucis longus beim Pes valgus Verh dtsch orthop Ges. 9 281–286 1910

*Kidner F C* The Prehallux (Accessory Scaphoid) in its Relation to Flat—Foot J Bone Jt Surg 11 831–837 1929

*Lange M* Orthopadisch—Chirurgische Operationslehre J F Bergmann Munchen 1951

*Lanz T v & Wachsmuth W* Praktische Anatomie J S Springer Berlin 1935

*Leavitt D C* Subastragaloid Arthrodesis for the Os Calcis Type of Flatfoot Amer J Surg 59 501–505 1943

*Milch H* Reinforcement of the Deltoid Ligament for Pronated Flat Foot Surg Gynec Obstet 74 876–881 1942

*Miller O L* A Plastic Flat Foot Operation J Bone Jt Surg 9 84 91 1927

*Müller E* Sehnentransplantation und Verhalten der Sehnen beim Plattfusse Zbl Chir *30* 40–42 1903

*Niederecker K* Operationsverfahren zur Behandlung des Plattfusses Chirurg 4 182–183 1932

*Niederecker K* Beiträge zur Entstehung des Plattfusses auf Grund von Muskelanomalien an Hand eines grösseren Operationsmaterials Z Orthop *79* 499–518 1950

*Niederecker K* Der Plattfuss F Enke Stuttgart 1959

*Nordenfelt P J* Kann der Plattfuss im Kindesalter ohne Einlagen effektiv behandelt werden Acta paediat *30* 94–102 1942

*Penners R* Die operative Behandlung des Plattfusses Münchner Med Wschr *101* 957–962 1959

*Picard J J & Mimran R* Opération de Grice Rev Chir orthop 47 590–597 1961

*Priester E S* Das Plattfussproblem Z Orthop *90* 195–207 1958

*Schede F* Die Operation des Plattfusses Z orthop Chir *59* 528–538 1929

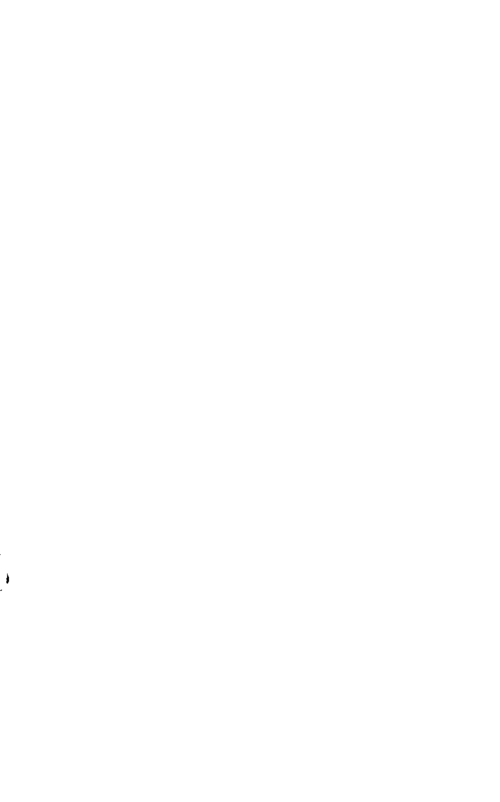
*Schaffer W* Zur operativen Behandlung des jugendlichen Plattfusses Wien klin Wschr *63* 834–836 1951

*Stracker O* Die Pathogenese des kindlichen Knickfusses Z Orthop *83* 353–365 1953

*Timmer H* Der Zusammenhang des Pes valgus beim Kinde und des Pes calcaneus beim Neugeborenen Z orthop Chir 45 35–40 1924

*Wetzenstein H* The Significance of Congenital Pes Calcaneo valgus in the Origin of Pes Plano valgus in Childhood Acta orthop Scandinav *30* 64–72 1960

*Young C S* Operative Treatment of Pes Planus Surg Gynec Obstet *68* 1099–1101 1939



Acta orthop Scandinav XXXV 257–263 1965

From the Department of Pathology II University of Uppsala Uppsala Sweden
(Head Professor B Engfeldt )

# DISTRIBUTION PER VOLUME BONE TISSUE OF CALCIUM PHOSPHORUS AND NITROGEN FROM INDIVIDUALS OF VARYING AGES AS COMPARED WITH DISTRIBUTION PER UNIT WEIGHT

*By*

J STRANDH and H NORLEN

Variations with age in the composition of bone tissue have been demonstrated by means of chemical analyses in investigations of both human material and material from various species of animals

For this purpose the degree of mineralization has been expressed either as a ratio Ca/N or P/N or as the weight per cent of calcium or phosphorus Variations in the composition of the mineral salts have been measured in terms of the Ca/P ratios

Thus *Baker Butterworth & Langley* (1) *Rogers Weidman & Parkinson* (2) and *Dickerson* (3) have investigated human compact bone tissue dissected free of soft tissues and have found that the Ca/N ratio increases with age When the concentrations of calcium and nitrogen was determined as percentages by weight it was found that the amount of calcium increased with age while that of nitrogen decreased *Dickerson* also determined the phosphorus content and found a somewhat lower P/N ratio during the foetal stage and the first years of life no variations in the Ca/P ratio could be detected

*Vogt* (4) has made similar determinations of calcium phosphorus and nitrogen in spongious bone tissue from crista ilica he found no definite variation with age for the Ca/N ratio but the percentages of calcium and nitrogen both increased with age *Vogt* also found that the concentration of phosphorus and the P/N ratio both reached a maximum at about 40–50 years of age while the Ca/P ratio was at a minimum at this age

*Strobino & Farr* (5) *Cartier* (6) *Weidman & Rogers* (7) and others

have investigated different animal species and have demonstrated a corresponding increase in the Ca/N ratio with age. *Weidman & Rogers* investigated the rabbit and the rat and found in addition a certain variation with age of the Ca/P ratio which sank for a short period after birth and subsequently increased. The highest Ca/P ratios were found in full grown animals.

*Strandh* (8) has studied the variations with age in the composition of Haversian systems. These were dissected from ground sections of compact bone tissue from human subjects aged 9 months, 6 years, 17 years, 52 years and 76 years. *Strandh* found that the Ca/N ratio increased with age in agreement with results of the microscopic investigations of bone tissue cited above. The P/N ratio was found to be lower for the nine months subject than for the older subjects, but the latter showed no definite variations with age. The Ca/P ratio was relatively high for the nine months infant, lower for the six year old child and increased with age for the other individuals.

The methods of studying the mineralization of bone tissue which have hitherto been employed, whether by way of the Ca/N, P/N and Ca/P ratios or by determining the percentages by weight of the three elements, give no information regarding any variations in density. Moreover, the presence of water and organic material in the bone tissue often makes it difficult to define the weight exactly. It was therefore considered of interest to supplement current knowledge on this topic as outlined above with determinations of the weight by volume of Ca, P and N in bone tissue at various ages.

## MATERIAL AND METHODS

The investigation was carried out on compact bone tissue from human femur diaphyses taken from autopsies comprising 49 cases aged between 22 days and 90 years, all free of any known skeletal diseases. Previous to investigation the bone material was stored at −20° C.

Cross sections of the femur diaphyses were ground down to a thickness of 350 μ. They were microradiographed with a Philips X-ray PW 1010/20 at 30 kV and 20 mA. Under guidance of the microradiograms parallelepipeds of lamellar bone (ca 500 μ) of periosteal or endosteal type were dissected from each femur diaphysis. Portions containing canal systems were avoided and bone tissue was selected which had an X-ray absorption closely to that of interstitial lamellar bone which always shows the highest X-ray absorption.

The material was divided into the following age groups: under 1 year, 1–10 years, 11–20 years, 21–30 years, 31–50 years, 51–70 years and 71–90 years. In the material from the 71–90 age group there was almost complete absence of both periosteal and endosteal lamellar bone. In this group highly mineralized Haversian systems were

*The Or[illegible] in Different Age Groups of Calcium, Phosphorus and Nitrogen in [illegible] and Haversian Systems expressed as Percentage by Weight and as Weights per unit Volume, Density of the Bone Tissue and the Weight Ratios Ca/N, P/N and Ca/P. Mean Values and the Standard Deviation of the Mean*

| Age group | | [illegible] | 1–10 y | 11–20 years | 21–30 years | 31–50 years | 51–70 years | 71–90 years | 1–90 years |
|---|---|---|---|---|---|---|---|---|---|
| Number of [illegible] | | 6 | | 7 | 4 | 10 | | | 10 |
| Type of [illegible] | | [illegible] | | | | | | | Haversian systems |
| Density | | 1.79 ± 0.02 | 1.87 ± 0.02 | 1.90 ± 0.01 | 1.90 ± 0.03 | 1.91 ± 0.02 | 1.94 ± 0.01 | | 1.91 ± 0.02 |
| Percentage by weight | Ca | 23.8 ± 0.[illegible] | 24.9 ± 0.3 | [illegible]5.0 ± 0.3 | 25.9 ± 0.5 | 26.4 ± 0.1 | 26.5 ± 0.2 | (27.0) | 26.2 ± 0.2 |
| | P | 10.5 ± 0.2 | 10.9 ± 0.1 | 11.2 ± 0.1 | 11.1 ± 0.2 | 11.1 ± 0.1 | 11.[illegible] ± 0.1 | (11.[illegible]) | 10.[illegible] ± 0.1 |
| | N | 4.64 ± 0.02 | 4.55 ± 0.07 | 4.48 ± 0.07 | 4.45 ± 0.10 | 4.43 ± 0.04 | 4.29 ± 0.04 | (4.34) | 4.47 ± 0.05 |
| Weight per unit volume (μg/μl) | Ca | 427 ± [illegible] | 449 ± 5 | 470 ± 7 | 492 ± 11 | 507 ± 5 | 514 ± [illegible] | ([illegible]20) | 50[illegible] ± 5 |
| | P | 188 ± 3 | 205 ± 2 | 213 ± 3 | 211 ± 5 | 214 ± 3 | 216 ± 3 | (217) | 211 ± 3 |
| | N | 83 ± 1 | 85 ± [illegible] | 85 ± 1 | 84 ± 1 | 84 ± 1 | 83 ± 1 | | 86 ± 1 |
| Ratios | Ca/N | 5.13 ± 0.07 | 5.28 ± 0.09 | [illegible].57 ± 0.11 | 5.86 ± 0.20 | 6.01 ± 0.05 | 6.17 ± 0.09 | (6.06) | 5.88 ± 0.07 |
| | P/N | [illegible]24 ± 0.0[illegible] | 2.40 ± 0.04 | 2.52 ± 0.04 | 2.52 ± 0.09 | 2.55 ± 0.04 | 2.61 ± 0.03 | (2.53) | 2.46 ± 0.03 |
| | Ca/P | 2.28 ± 0.03 | 2.20 ± 0.02 | 2.2[illegible] ± 0.02 | 2.33 ± 0.01 | 2.37 ± 0.02 | 2.38 ± 0.03 | | 2.40 ± 0.01 |

The figures in brackets under the age group 71–90 years are values calculated to be applicable for a three per cent higher degree of mineralization than that in highly mineralized Haversian systems.

have investigated different animal species and have demonstrated a corresponding increase in the Ca/N ratio with age. *Weidman & Rogers* investigated the rabbit and the rat and found in addition a certain variation with age of the Ca/P ratio which sank for a short period after birth and subsequently increased. The highest Ca/P ratios were found in full grown animals.

*Strandh* (8) has studied the variations with age in the composition of Haversian systems. These were dissected from ground sections of compact bone tissue from human subjects aged 9 months, 6 years, 17 years, 52 years and 76 years. *Strandh* found that the Ca/N ratio increased with age in agreement with results of the microscopic investigations of bone tissue cited above. The P/N ratio was found to be lower for the nine months subject than for the older subjects but the latter showed no definite variations with age. The Ca/P ratio was relatively high for the nine months infant, lower for the six year old child and increased with age for the other individuals.

The methods of studying the mineralization of bone tissue which have hitherto been employed, whether by way of the Ca/N, P/N and Ca/P ratios or by determining the percentages by weight of the three elements, give no information regarding any variations in density. Moreover, the presence of water and organic material in the bone tissue often makes it difficult to define the weight exactly. It was therefore considered of interest to supplement current knowledge on this topic, as outlined above, with determinations of the weight by volume of Ca, P and N in bone tissue at various ages.

## MATERIAL AND METHODS

The investigation was carried out on compact bone tissue from human femur diaphyses taken from autopsies comprising 49 cases aged between 22 days and 93 years, all free of any known skeletal diseases. Previous to investigation the bone material was stored at —20° C.

Cross sections of the femur diaphyses were ground down to a thickness of 350 µ. They were microradiographed with a Philips X-ray PW 1010/20 at 30 kV and 20 mA. Under guidance of the microradiograms parallel epipeds of lamellar bone (ca 500 µ) of periosteal or endosteal type were dissected from each femur diaphysis. Portions containing canal systems were avoided and bone tissue was selected which had an X-ray absorption closely to that of interstitial lamellar bone which always shows the highest X-ray absorption.

The material was divided into the following age groups: under 1 year, 1–10 years, 11–20 years, 21–30 years, 31–50 years, 51–70 years and 71–90 years. In the material from the 71–90 age group there was almost complete absence of both periosteal and endosteal lamellar bone. In this group highly mineralized Haversian systems were

measured per unit volume while it decreases with age if measured per unit weight This and the increase of density with age show that the changes with age do not consist of a replacement of organic material by mineral salt but rather a deposition of this salt in cavities such as osteocyte lacunes and central canals This conclusion is in agreement with the results obtained by *Sisson* and co workers (11) and others from microradiographic investigations of normal bone tissue at various ages

The increase with age of the calcium content but not the phosphorus content in the higher age groups together with the increase in the Ca/P ratio suggests that a further calcium salt is deposited as well as apatite *Bergstrom & Bell* (12) and *Burns & Henderson* (13) have shown that the carbonate content of bone tissue increases with age and it is therefore reasonable to interpret the above mentioned variations in terms of a filling up of the cavities with mineral salt which in the higher age groups consists partly of calcium carbonate

## SUMMARY

Determinations of the weight by volume of calcium phosphorus and nitrogen in human compact bone was performed on 49 autopsy cases aged between 22 days and 90 years The calcium content was found to increase with age The phosphorus content increases with age up to the 11–20 age group and appears thereafter to be unaltered The increase of these elements exhibits a larger percentage if the content of them is expressed in terms of unit weight per unit volume rather than as a percentage by weight The nitrogen content decreases with age up to the 51–70 age group when measured as a percentage by weight when expressed in terms of unit weight per unit volume it shows no variation with age The density of the bone tissue was found to increase significantly with age of to the 1–10 group and it is significantly higher in the 51–70 age-group than in the 1–10 age-group

## RÉSUMÉ

Des déterminations du poids par le volume du calcium du phosphore et de l azote dans le tissu compact des os humains ont ete pratiquées dans 49 cas d autopsie de sujets âgés de 22 jours a 90 ans

On a constate que la teneur en calcium augmente avec l age La teneur en phosphore augmente avec l age jusqu au groupe entre 11 et

20 ans et semble rester inchangée par la suite. L'augmentation de ces éléments représente un plus large pourcentage de la teneur si celle-ci est exprimée en unité de poids par unité de volume plutôt qu'en un pourcentage du poids. La teneur en azote décroît avec l'âge jusqu'au groupe entre 51 et 70 ans lorsqu'elle est mesurée comme un pourcentage du poids; lorsqu'elle est exprimée en unité de poids par unité de volume il n'y a aucune variation avec l'âge. On a constaté que la densité du tissu osseux augmente d'une manière notoire avec l'âge dans le groupe de 1 à 10 ans et elle est sensiblement plus élevée dans le groupe d'âge de 51 à 70 ans que dans celui de 1 à 10 ans.

## ZUSAMMENFASSUNG

Bestimmungen des Volumengewichtes von Calcium, Phosphor und Stickstoff im menschlichen Kortikalknochen wurde an 49 Autopsiefällen, die 22 Tage bis 90 Jahre alt waren, vorgenommen. Der Calciumgehalt nimmt mit dem Alter zu. Der Phosphorgehalt nimmt mit dem Alter bis zur 11–20 jährigen Gruppe zu, um hernach unverändert bestehen zu bleiben. Die Zunahme dieser Elemente weist einen höheren Prozent auf, wenn ihr Inhalt im Verhältnis von Gewichtseinheit per Volumeneinheit anstatt als Gewichtsprozent ausgedrückt wird. Der Stickstoffgehalt nimmt mit dem Alter bis zur 51–70 jährigen Altersgruppe ab, wenn er als Gewichtsprozent gemessen wird. Wenn er jedoch im Verhältnis von Gewichtseinheit zu Volumeneinheit ausgedrückt wird, zeigt er keine Veränderung mit dem Alter. Es wurde gefunden, dass die Dichtigkeit des Knochengewebes mit dem Alter bis zu der 1–10 Gruppe bedeutend zunimmt und dass sie in der 51–70 jährigen bedeutend grösser ist als in der 1–10 jährigen Gruppe.

## ACKNOWLEDGEMENT

This investigation was supported in part by a grant from the Swedish Medical Research Council, in part by a P.S.H. research grant (D 1652) from the United States Public Health Service.

## REFERENCES

1. *Baker, S. L., Butterworth, E. C. & Langley, F. A.*: The calcium and nitrogen content of human bone tissue cleaned by micro-dissection. Biochem. J. *40*: 391, 1946.
2. *Rogers, H. J., Weidmann, S. M. & Parkinson, A.*: Studies on the skeletal tissues. II. The collagen content of bones from rabbits, oxen and humans. Biochem. J. *50*: 537, 1952.

3 *Dickerson J W T* Changes in the composition of the human femur during growth Biochem J *82* 56 1962

4 *Vogt J H* Investigations on the bone chemistry of man I Ash content of the spongy substance of the iliac crest Acta med scand *135* 221 1949

5 *Strobino L J & Farr L E* The relation to age and function of regional variations in nitrogen and ash content of bovine bones J biol Chem *178* 599 1949

6 *Cartier P* Variations des anions organiques de l os (citrates et lactates) au cours de la croissance C R Soc Biol (Paris) *143* 37 1949

7 *Weidmann S M & Rogers H J* Studies on skeletal tissues 5 The influence of age upon the degree of calcification and the incorporation of 32P in bone Biochem J *69* 338 1958

8 *Strandh J* Microchemical studies on single Haversian systems III Distribution of calcium phosphorus and nitrogen in microscopic bone tissue structures of varying ages Biochimica e Biologia Sperimentale *1* 60 1961

9 *Strandh J* Microchemical studies on single Haversian systems I Methodological considerations with special reference to variations in mineral content Exp Cell Res *19* 515 1960

10 *Strandh J* Microchemical studies on single Haversian systems II Methodological considerations with special reference to the Ca/P ratio in microscopic bone structures Exp Cell Res *21* 406 1960

11 *Sissons H A Jowsey J & Stewart L* The microradiographic appearance of normal bone tissue at various age In X ray Microscopy and Microanalysis Ed A Engstrom V E Cosslett & H H Pattee Elsevier Publ Co Amsterdam London New York Princeton 1960 pp 206–215

12 *Bergstrom W H & Bell F H* The relationship of sodium and potassium in Bone J biol Chem *206* 711 1954

13 *Burns C M & Henderson N* The mineral constituents of bone II The influence of age on the mineral constituents of bones from kittens and pups Biochem J *30* 1 1207 1936

Acta orthop. Scandinav. XXXVI, 264–278, 1965

From Institute of Experimental Research in Surgery, University of Copenhagen
(Head: H. H. Wandall) and
The Orthopedic Hospital, Department I, Copenhagen (Head: A. Bertelsen)
with support from Fondet til Videnskabens Fremme

# THE VASCULAR SUPPLY TO THE FEMORAL HEAD FOLLOWING DISLOCATION OF THE HIP JOINT

## *An Experimental Study in New Born Rabbits*

*By*

H. Bohr, K. Baadsgaard and Ph. Sager

In congenital dislocation of the hip joint disturbances in the development of the femoral head can be observed. Retarded appearance of the ossification centre or condensation and fragmentation is seen with varying frequency according to the age and the method of treatment (*Esteve* 1960 and *Wilkinson & Carter* 1960). Little is known about the origin of these changes, but the resemblance with the disturbances in Legg-Calvé-Perthes' disease has been pointed out (*Massie* 1951 and *Meyer* 1963). It is generally agreed that the changes in Legg-Calvé-Perthes' disease are due to disturbances in the vascular supply to the femoral head producing ischemic necrosis (*Jonsäter* 1953). Changes in the femoral head of dogs similar to those of Legg-Calvé-Perthes' disease have been described by *Moltzen-Nielsen* (1938). Angiographic investigation of such cases has shown that devascularization is present corresponding to the lesion and that hyperemia has developed in the surrounding tissue (*Hulth* 1962).

The present investigation has been carried out to study the effects of a disturbance of the vascular supply to the femoral head produced by traumatic dislocation of the hip joint in new born rabbits.

### METHODS

In two days old rabbits a dislocation of the right hip joint was produced by a constant pressure in an upward direction on the adducted femur. A small click was

heard as the femoral head slipped over the rim of the acetabulum and the greater trochanter could be felt projecting outwards The animals showed only little reaction to this manipulation and seemed to be able to move about without pain No deaths occurred In each animal the left hip served as control

X ray examinations were performed with regular intervals to observe the changes which developed

20 animals were included in the experiment and as seen in the table 19 were sacrificed from 2 days to 7 weeks and one animal 17 weeks after the dislocation was performed In intraperitoneal Nembutal anaestesia the heparinized animals were bled from the inferior vena cava A cannula was placed in the aorta and the vascular system perfused with saline of body temperature to wash out the blood Perfusion was continued with a 2 per cent solution of Berline Blue in saline in an amount of 100–300 ml according to the size of the animal This was followed by perfusion of a 25 per cent mixture of Micropaque in saline with 2 per cent Berline Blue The colouring of the skin and the membranes was noted and venous return of the perfundated solution was observed during the perfusion which was continued for an hour at a pressure of 100 mm Hg

After fixation in 4 per cent formaline the animals were dissected and the pelvis with attached femora removed for X ray examination and decalcification in formic acid

Angiographic examination of the femur and acetabulum was performed with soft X rays from a Machlett AEG X ray tube regenerated at 25 kV max and 20 mA Exposures were made on Kodaline film at a distance of 50 cm from the focus

The specimens were then embedded in paraffin and cut on a microtome into sections alternating 200 µ and 7 µ in thickness The thin sections were prepared for ordinary histological investigation after staining with Haematoxylin Eosin while the thick sections were treated according to the method of Spalteholz to observe the course of the vessels

## RESULTS

Repeated X ray examinations of the living animals showed dislocation of the hip joint with lateral and posterior displacement of the femoral head persisting throughout the time of observation (Figs 1 and 2) In 3 of the animals epiphysiolysis of the femoral head and in 2 animals a fracture of the femoral shaft resulted from the manipulation These animals are included in the total material and the sequels of epiphysiolysis will be described separately

The dissection disclosed that disruption of the ligamentum teres occurred in every case of dislocation in the hip joint In those animals which were sacrificed during the first two weeks it could be seen that the femoral head was displaced through the capsule 2 to 3 weeks after the dislocation the original capsule could no longer be identified and a regular false joint with cartilage and fibrous capsule had developed above and behind the acetabulum (Fig 3) Dysplastic changes of the

# RESULTS

| ANIMAL NO | INTERVAL FROM LUXATION TO DEATH OF ANIMAL | LESION PRODUCED | X RAY EXAMINATION AND GROSS APPEARANCE OF SPECIMENS | | | | | | | ALTERATIONS IN STRUCTURE AND VASCULARISATION | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LIGAMENTUM TERES | JOINT CAPSULE | VARUS POSITION OF FEMORAL HEAD | ANTEVERSION O FEMORAL HEAD | DEFORMITIES OF FEMORAL HEAD | DIMINISHED CENTRE OF OSSIFICATION OF FEMORAL HEAD | ACETABULA DYSPLASIA | NECROTIC CHANGES IN THE UPPER FEMORAL EPIPHYSIS | INCREASED THICKNESS O JOINT CARTILAGE | VESSELS PENETRATING THE EPIPHYSIAL PLATE | EQUENCES OF PENETRATION OF THE EPIPHYSIAL PLATE |
| 1 64 24 | 2 DAYS | L A ON | UPT RED | RU TURED | | - | - | + | - | + | | - | - |
| 2 4 2 | LA S | E F SO I S | NTACT | NTACT | - | - | - | - | - | - | - | - | - |
| 3 J 22 II | 5 A S | U ATION | RU TURED | RUPTURED | - | - | - | + | + | + | | + | |
| 4 4 24 II | 4 LA S | FRACT OF FEM D AI | ITACT | NTACT | - | - | - | - | - | - | - | - | - |
| 5 4 III | 5 DA S | LUXAT ON | RUPTURED | RU TURED | + | + | - | + | + | + | | + | |
| 6 63 4 2 III | 7 DAYS | LUXAT ON | RUP URED | RUPTURED | + | + | - | + | + | + | | + | |
| 7 63 422 IV | DA S | E P YSO L S S | NTACT | NTACT | - | | | - | - | - | - | - | - |
| 8 64 076 I | 12 DAYS | LUXAT ON | RUPTURED | RU TURED | + | + | + | + | + | + | | + | |
| 9 4 076 II | 4 DAYS | FRACT OF M DIAPH | INTACT | NTACT | - | | - | - | - | - | - | - | - |
| 10 64 077 I | 4 DAYS | LU AT ON | RUPTURED | RUPTURED | + | + | + | + | + | + | + | + | |
| 11 63 96 I | 4 DAYS | LUXATION | RUPTURED | RU TURED | + | + | + | + | + | - | + | + | |
| 12 64 076 II | 6 DAYS | LUXATION | RUPTURED | RU TURED | + | + | + | + | + | + | + | + | |
| 13 64 077 II | 8 C YS | E PHYSIO LY IS | NTACT | NTACT | - | - | - | | - | - | - | - | - |
| 14 64 077 III | 9 DA S | LUXATION | RU TURED | RUPTURED | + | + | + | + | + | + | + | + | |
| 15 63 86 | 3 WEE S | IXAT N | RU TURED | RU TURED | + | + | + | + | + | + | + | + | |
| 16 63 296 II | 4 W EKS | J ATIO | RU U D | RUPTURED | + | + | + | - | + | - | + | | + |
| 17 3 — | TE S | | IRE | RED | + | + | + | - | + | - | + | | + |
| 18 3 96 | AEE | N | ED | U ED | + | + | + | - | + | - | + | | + |
| 19 3 6 | 7 WEE S | AT ON | RJ TURED | RUPTURED | + | + | + | - | + | - | + | | + |
| 0 63 6 | 7 WEE S | U ON | RUPTURED | UPTU ED | + | + | + | | + | - | + | | + |




*Fig 1*
Radiograph 11th day Animal 11
Right hip dislocated Dysplastic changes of the acetabulum and the femoral head




*Fig 2*
Radiograph 29th day Animal 18
Persistent dislocation A new acetabulum has been formed
Varus position of the femoral head

acetabulum were present from the 3rd day and gradually increased The head of the femur showed anteversion and varus position from the 7th day of dislocation and throughout the following period In the youngest animals the epiphysis was reduced in size compared with the normal side but this difference later decreased A slight shortening of the femoral shaft could be measured in most cases but not exceeding a few per cent The neck of the femur seemed shorter and somewhat broader than the normal

X ray examination of the removed specimens shows that the ossification centre of the femoral head normally appears during the first few days of life Compared to this the side of the lesion will show delayed appearance and during the first 3 weeks retarded growth of the centre which often displays irregular outline and condensation (Fig 4) Although these changes later disappear the femoral head often remains somewhat flattened and broad

Angiographic studies and Spalteholz preparations of the decalcified specimens show that the normal blood supply to the femoral head

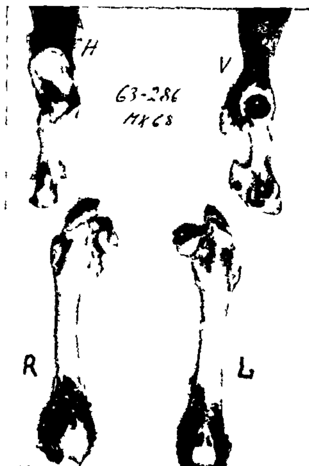



*Fig. 3*
Dissection specimens 7th week. Animal 19.
Varus position, anteversion and some malformation on the right femoral head.
New acetabulum formed.

comes from vessels in the ligamentum teres and on the postero-medial side of the femoral neck.

As a result of dislocation the femoral head is almost completely avascular during the first week (Fig. 5). From the second week revascularization takes place through vessels from the trochanteric region and by vessels perforating the epiphysial plate from the metaphysial side (Figs 6 and 7). Such perforating vessels were never seen in the normal hip; detailed description appears below under the histological examination. During the following 2–3 weeks hypervascularization is observed in the femoral head. This hyperemia gradually

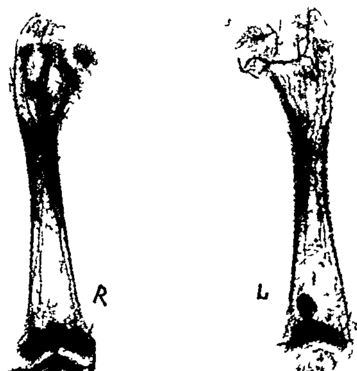



Fig [illegible]
Radiograph 14th day Anim I 11
Varus position of the right femoral head
Smaller irregular and condensed centre of ossification

diminishes and the perforations of the epiphyseal plate cannot be demonstrated from the 4th week following the dislocation although the vessels still show a somewhat abnormal and irregular distribution

The examination of the histological slides shows but *few functioning* vessels in the head of the femur during the *first week after dislocation* of the hip The joint cartilage *appears normal while the central part* of the epiphysis shows *undefined structure with pycnotic remains of* cell nuclears from necrotic *marrow and thrombosed vessels Around* this centre especially *along a line from the previous attachment of* the ligamentum teres *towards the epiphyseal plate the cartilage ap*pears partly necrotic *with pycnotic cell nuclear and [illegible] intercellular* substance This is true *also of the part of the epiphyseal plate* which is in contact with the *degenerated cartilage [illegible] from the corre*

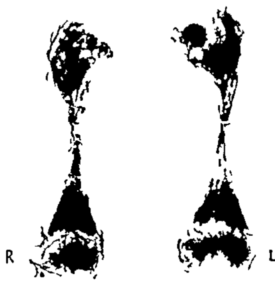



*Fig. 5*
Angiograph 7th day. Animal 6.
The right femoral head is avascular except a smaller part laterally.




*Fig. 6*
Angiograph 3rd week. Animal 15.
Hypervascularization of the right femoral head.
Abnormal vascular pattern.



*Fig 7*

Spalteholz preparation 16th da  Animal 12  Right femoral head
Vessels perforating central part of the epiphysial plate



*Fig 8*

Histological section 7th day  Animal 6  Right femoral head
Necrotic changes in the central part of the femoral head and epiphysial plate
Vessel penetrating from the metaphysis

*Fig 9*
Histological section 14th day. Animal 10. Right femoral head.
Central perforation of the epiphysial plate by vessels and formation of bone bridge

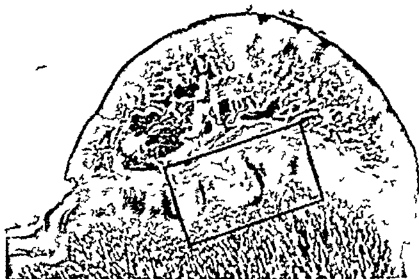


*Fig 10*
Histological section 4th week. Animal 16. Right femoral head



*Fig 11*
Detail from Fig 10
Continuity of the epiphysial plate has been re established
Large bony projection from the epiphysis

sponding metaphysial part dilated vessels are seen penetrating towards the epiphysis (Fig 8)

During the following weeks these vessels perforate the epiphysial plate and along with vessels and invading connective tissue ossification takes place establishing a bone bridge between the metaphysis and the ossification centre of the epiphysis (Fig 9) Regeneration of the cartilage cells in the epiphysis and the epiphysial plate takes place with the appearance of normal cell proliferation During the following weeks the bone bridges between the metaphysis and epiphysis are gradually disconnected at the metaphysial end and about the 4th week after dislocation of the hip the continuity of the epiphysial plate is reestablished leaving irregularities corresponding to the remaining bone projections from the epiphysis (Figs 10 and 11)

As previously mentioned epiphysiolysis occurred instead of dislocation in 3 animals In these cases the vascular supply to the femoral head seems undisturbed and the histological sections show that disruption has occurred through the metaphysial side of the epiphysial plate During the observation time the epiphysial plate increases in

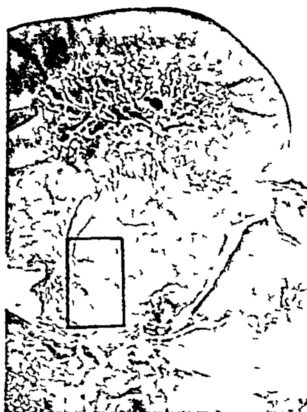


*Fig. 1?*
Histological section 11th day. Animal 7. Right femoral head. Epiphysiolysis. Normal centre of ossification.

thickness with elongation of the columns of cartilage cells and no ossification develops here (Figs. 12 and 13).

## DISCUSSION

It was shown by *Langenskjold, Sarpio & Michelsson* (1962) that the characteristic deformities in the acetabulum and the femoral head following congenital dislocation in man can be produced by traumatic dislocations of the hip joint in new born rabbits. In the present investigation similar dysplastic changes have been demonstrated. Our examinations have furthermore shown development of ischemic ne-



*Fig 13*
Detail from Fig 12
Greatly broadened epiphysial plate without endochondral ossification

crosis in the ossification centre and degeneration of cartilage cells in the epiphysis with perforation of the epiphysial plate by vessels from the metaphysis Such perforations have previously been described among others by *Trueta & Amato* (1960) who through surgical interventions on 6 weeks old rabbits produced devascularization of the proximal tibia epiphysis While these authors observed the development of permanent epiphysiodesis in the area of intervention the bone bridges in our cases were only transistory with later reestablishment of the continuity of the epiphysial plate Although this discrepancy may be due to the difference in degree of the intervention it is in our opinion more likely due to a different reaction in the younger animals

Our cases of epiphysiolysis showed no interference with the vascular supply to the epiphysis and resulted in a broadening of the epiphysial plate. This can be compared with the similar disturbances described by *Truela & Amato* (1960) following interference with the vascular supply on the metaphysial side of the epiphysial plate.

Results of surgical interventions in the vascular supply to the femoral head of rabbits have been described by different authors. Thus *Lemoine* (1957) in examinations of 2–7 weeks old animals observed fragmentation and flattening of the femoral head after ligation of the ligamentum teres or disruption of the posterior inferior vessel to the epiphysis. *Rokkanen* (1962) has shown that similar disturbances of the vascular supply to the femoral head of adult rabbits interfere but little with the development of bone and cartilage. In cases of permanent dislocations, however, necrosis of the bone was often observed.

The results of the quoted works and those of our observations may contribute to the understanding of the dysplastic changes of the femoral head in various age groups, including Legg-Calvé-Perthes disease. Further investigations along these lines are needed and have been planned.


SUMMARY

Following traumatic dislocation of the hip joint in 20 new-born rabbits, characteristic changes could be seen with anteversion and varus position of the femoral head as well as dysplastic deformations of the acetabulum. The animals were sacrificed 2 days to 7 weeks after the dislocation. Injection studies revealed an almost complete devascularization of the displaced femoral head within the first week. This was followed by revascularization with an intermediate phase of hyperemia of the femoral head. On sections through the femoral head histological examination as well as preparations with Spalteholz technic showed ischemic necrosis of the ossification centre and degenerative changes in the cartilage of the epiphysis and the epiphysial plate. *From the first week after dislocation vessels were observed perforating the epiphysial plate* from the metaphysis, resulting in the formation of bone bridges between the metaphysis and the epiphysis. These perforations were transitory and from the 4th week they could only be traced as irregularities in the epiphysial plate.

The *significance of these findings* is discussed in relation to the changes observed in congenital dislocation of the hip as well as in Legg-Calvé-Perthes disease.

RESUME

A la suite d une dislocation traumatique de la hanche chez 20 lapins nouveau nes des changements caracteristiques ont ete constates ante version et position varus de la tete femorale aussi bien que déforma tion dysplastique de la cavite cotyloide

Les animaux ont ete sacrifies entre 2 jours et 7 semaines apres la dislocation

Une étude au moyen d injections a revele une dévascularisation pres que complete de la tete fémorale deplacee dans le courant de la pre miere semaine Il s est produit ensuite une revascularisation avec une phase intermédiaire d hyperhemie de la tete femorale En sectionnant la tete femorale l examen histologique comme les preparations selon la technique de Spalteholz ont montre une necrose ischemique du centre d ossification et des modifications degeneratives du cartilage de l épiphyse et de la plaque epiphysaire Dejà la premiere semaine apres la dislocation on a observe des vaisseaux perforant la plaque epi physaire en partant de la metaphyse resultant dans la formation d un osseux entre la metaphyse et l epiphyse Ces perforations etaient tran sitoires et a partir de la 4eme semaine elles ne pouvaient etre dis cernees que comme des irregularites de la plaque epiphysaire

La signification de ces trouvailles est discute en relation avec les modifications observées dans la dislocation congenitale de la hanche aussi bien que dans la maladie de Legg Calve Perthe

ZUSAMMENFASSUNG

Nach traumatischer Luxation des Huftgelenkes bei 20 neugeborenen Kaninchen konnten charakteristische Veranderungen wie Anterversion und Varusposition des Femurkopfes als auch dysplastische Verbildun gen des Acetabulum beobachtet werden

Die Tiere wurden 2 Tage bis 7 Wochen nach der Luxation getotet

Untersuchungen mittels Injektion zeigten einen beinahe vollstandi gen Gefassverlust des luxierten Femurkopfes innerhalb der ersten Woche Dies war von einer Revaskularisierung mit einer dazwischen liegenden Phase von Hyperämie des Femurkopfes gefolgt Die histo logische Untersuchung von Scheibenschnitten des Femurkopfes sowie auch Praparate mit der Spalteholtz Technik zeigte ischämische Ne krose des Ossikationszentrums und degenerative Veränderungen des Epiphysenknorpels und der Epiphysenplatte Von der ersten Woche nach der Luxation wurden Gefässe beobachtet die die Epiphysenplatte

von der Metaphyse her durchbrachen und die Bildung von Knochenbrücken zwischen der Metaphyse und der Epiphyse zum Ergebnis hatten. Diese Durchbrüche waren vorübergehend und von der vierten Woche an konnten sie nur als Unregelmässigkeiten in der Epiphysenplatte nachgewiesen werden.

Die Bedeutung dieser Befunde wird unter Bezugnahme auf die Veränderungen, die bei angeborener Hüftverrenkung und bei der Legg-Calvé-Perthes-Erkrankung beobachtet werden, besprochen.

## REFERENCES


1. *Esteve, R.*: Congenital Dislocation of the Hip. J. Bone Jt Surg. *42-B*, 253–263, 1960.
2. *Hulth, A., Norberg, I. & Olsson, S. E.*: Coxa Plana in the Dog. J. Bone Jt Surg. *44-A*, 918–930, 1962.
3. *Jonsäter, S.*: Coxa Plana. Acta orthop. Scandinav. Suppl. 12, 1953.
4. *Langenskiöld, A., Sarpio, O. & Michelsson, J. E.*: Experimental Dislocation of the Hip in the Rabbit. J. Bone Jt Surg. *44-B*, 209–215, 1962.
5. *Lemoine, A.*: Vascular Changes after Interference with Blood Flow of Femoral Head of Rabbit. J. Bone Jt Surg. *39-B*, 763–777, 1957.
6. *Massie, W. K.*: Vascular Epiphysial Changes in Congenital Dislocation of the Hip. J. Bone Jt Surg. 33-A, 284–306, 1951.
7. *Meyer, J.*: Mb. Calvé-Perthes and Dysplasia Epiphysialis Capitis Femoris. Address to the Danish Orthop. Assn. J. Bone Jt Surg. *45-B*, 433, 1963.
8. *Moltzen-Nielsen, H.*: Calvé-Perthes Krankheit. Malum deformans juvenilis coxae bei Hunden. Arch. wiss. prakt. Tierheilk. 72, 91–108, 1938.
9. *Rokkanen, P.*: Aseptic Necrosis of the Femoral Head. Acta orthop. Scandinav. Suppl. 58, 1962.
10. *Trueta, J. & Amato, V. P.*: The Vascular Contribution to Osteogenesis. 3. J. Bone Jt Surg. *42-B*, 571–587, 1960.
11. *Wilkinson, J. & Carter, C.*: Congenital Dislocation of the Hip. J. Bone Jt Surg. *42-B*, 669–688, 1960.

Acta orthop Scandinav XXXVI 279 293 1965

From the Institute of Experimental Research in Surgery
(Director H H Wandall M D ) University of Copenhagen
Surgical Department A (Head R Movin M D ) Frederiksberg Hospital
and Laboratory of Bone Physiology (Head Professor A Bertelsen M D )
Orthopaedic Hospital Copenhagen Denmark

# MUSCLE PEDICLE BONE GRAFTS

## *An Experimental Study*

*By*

K Baadsgaard and S Medgyesi

After grafting of fresh autogenous bony material most of the osteocytes and the included soft tissues will perish before revascularization has taken place

It is generally accepted however that the most peripheral cells of the graft are able to survive by diffusion if the recipient site is favourable Apart from the action due to surviving cells it is known that bone grafts exert an inductor function upon the surrounding soft tissues (2) Furthermore the osteogenic tissue arising from the recipient site is assumed to have an affinity for the grafts which thereby exercise a conductor function

Nothing definite is known about the share of these individual functions in the final result but the most common view is that the mechanical properties of the graft and its inductor function are of cardinal importance whereas it is not believed to play any major role as an active participant in osteogenesis In the case of an inferior recipient site the induction may be deficient as well and this may result in poor healing of the graft

In order to obtain a more dependable osteogenetic action therefore it seemed natural to apply a bone graft which had preserved its blood supply and viability through a soft tissue pedicle

In the course of time clinical attempts at employing muscle pedicle bone grafts have in fact been made

It may be mentioned as a curiosity that *Phelps* (21) in 1891 was the first to transplant a muscle-pedicle bone graft from a dog to an

Aided by a grant from the Danish Science Foundation

osteomyelitic defect in a boy. The boy and the dog were on excellent terms, but the graft was expelled, and all subsequent attempts have been carried out as autotransplantations.

The method has been used for various purposes, most often to cover bony defects. *Watson Jones* (26), for instance, covered a large defect in the frontal bone with a pedicled graft consisting of the external lamina of the temporal bone, the temporal muscle serving as the pedicle.

Incidentally, the most common indication has been pseudarthrosis. *Payr* (20), in a case of mandibular pseudarthrosis, used a rib with skin and muscle as a pedicle, while *Cole* (4), for the same purpose, used a graft from the mandible itself with a pedicle of platysma. In pseudarthrosis of the humerus, *Codivilla* (3) used the axillary border of the scapula pedicled by the teres major and minor. For large defects of the tibia he used a piece of the fibula with preserved muscle attachment. *Cuneo & Bloch* (5), in femoral pseudarthrosis, used a pedicled sliding graft with intact muscles, taken from the femur distal to the pseudarthrosis. In congenital tibial pseudarthrosis *Reichel* (23) and *Farmer* (7) raised pedicled grafts from the contralateral tibia in several stages.

Furthermore, the method has been used to some extent in arthrodesis procedures. For example, in arthrodesis of the hip *Hibbs* (12, 11) used the greater trochanter with the gluteus medius as a pedicle and in arthrodesis of the knee he used the patella.

As far as experimental investigations are concerned, *Hellstadius* (10) arrived at a rather negative result, while *Davis & Taylor* (6), *Hartley & Silver* (9), and *Woodhouse & Farouk* (27) have reported more positive results.

Recently pedicled bone grafts have been used in the treatment of medial fractures of the femoral neck by *Moon* (17, 18, 19), and *Judet* (14), and in the treatment of pseudarthrosis by *Moon*. This has given rise to a renewed interest in the procedure.

The present study was undertaken in order to ascertain whether a fundamental difference between pedicled and free bone grafts could be demonstrated experimentally.

## TECHNIQUE AND MATERIAL

The experimental animals were 24 young, mature or nearly mature rabbits of mixed stock, weighing between 2 and 3.5 kg and ranging in age between 6 and 1? months. These rabbits were divided into two groups.

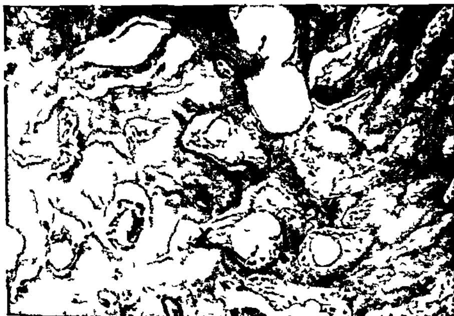


*Fig 1*
10th day Histological preparation of a pedicled cortical graft
Creeping substitution and periosteal callus × 125

Group I was used for comparing pedicled and free bone grafts 5 rabbits with cancellous and 5 with cortical grafts The right sided grafts were pedicled and the left sided ones free

The rabbits were anaesthetized by injecting Nembutal into an ear vein about 40 mg/kg body weight The operative sites were shaved and disinfected with iodine The bone grafts were cut with a rotating bone saw and the muscle pedicle was dissected to a length of 1 cm The cut surface of the grafts was isolated from the surroundings by polyethylene foil 0 05 mm thick.

The free grafts were dissected in exactly the same way but the muscle attachment was stripped from the periosteum The graft was fixed so as to be in touch with the cut-off muscle with a few sutures of non traumatic silk.

The cancellous grafts were obtained from the greater trochanter They measured approx 10 × 10 × 5 mm and were furnished with a strong muscle pedicle consisting mainly of the gluteus medius and minimus

The cortical grafts consisted of the dorso-radial part of the proximal end of the ulna They measured approx 20 × 5 × ? mm and consisted of full thickness compact bone one side of which carried an endosteal surface corresponding to the medullary cavity of the ulna The muscle pedicle covered more than half the periosteal surface and consisted mainly of the extensor carpi ulnaris muscle

Penicillin 300 000 units was injected i m The rabbits tolerated the operation well. There was no mortality and no infection



*Fig. 2*
10th day. Free cortical graft. The graft is necrotic and there is no callus. × 1[illegible]

The rabbits were killed 1, 3, 6, 10 and 13 days after the operation. Twenty four hours previously they had been injected with $^{45}$Ca 50 μC/kg into an ear vein and in the case of the cortical grafts with tetracycline 50 mg/kg.

Under i.v. Nembutal anaesthesia the heparinized rabbit was bled through the aorta. The vascular bed was rinsed with 500 ml saline solution of body temperature to which had been added amyl nitrite, and 500 ml of a mixture of equal parts India ink and physiological saline was injected. The injection pressure was 100 mg Hg. In all cases there was an unobstructed flow out through the vena cava and in 7/10 of the cases the injection was successful.

Half the specimen was fixed in formalin, decalcified in formic acid sodium formate, embedded in paraffin and cut into 7 μ sections, stained with haematoxylin eosin and van Gieson's connective tissue stain.

200–400 μ sections were made transparent by the Spalteholz method (24) and the course of the vessels was studied in a stereo microscope.

The other half was used for preparing undecalcified ground sections. The cortical grafts were embedded in methyl metacrylate according to a method described by *Løe* (16). After hardening the preparations were sawn off and manually ground to a thickness of 50–75 μ. From the cancellous grafts ground sections were prepared without preceding embedding.

The undecalcified ground sections were used for autoradiography by the contact method on Ilford Nuclear Research Plate G5 50 μ. The films were exposed for 4 days and developed in an Ilford Rapid Dental Developer.



*Fig 3*

3rd day Injection preparation of cortical bone Numerous vessels in the periosteum and in the pedicled graft none in the free graft × 25

The same sections of the cortical grafts were studied by fluorescence microscopy in ultraviolet light

Group II used for studying the histological changes during the further course consisted of 7 rabbits with cancellous and 7 with cortical grafts The operations were performed as described above but with a pedicled graft on both sides These rabbits were killed 1–7 weeks after the operation

Lastly one rabbit was used for investigation with ³ P This rabbit had operations on all 4 limbs On the 5th day ³ P 50 µC/kg was administered and 90 min later the rabbit was killed The soft tissues were removed from the preparations and the radiation activity was measured

## RESULTS

*Group I*

Histological study of the pedicled cancellous preparations showed the osteocytes to be of normal appearance apart from a narrow rim of empty lacunae close to the cut edge Only in one preparation was there a small well defined area most remote from the pedicle in which the lacunae were empty and another preparation showed scattered pyknotic nuclei The periosteum survived and showed on the 3rd day proliferation of osteoblasts On the 6th day there was periosteal callus and callus formation between the trabeculae close to the



*Fig 4*

Autoradiographs of cancellous grafts, the pedicled one on the left. The marked blackening around the pedicled graft represents callus formation × 5

cut surface. On the 10th day the entire preparation was surrounded by callus. There were no signs of resorption or creeping substitution.

In the free cancellous preparations the lacunae were empty or contained pyknotic nuclei and there were only a very few normal looking cells peripherally in the graft. In the earliest preparations the periosteum was necrotic. On the 6th day there was incipient regeneration of periosteum and on the 13th day periosteal callus.

The pedicled cortical preparations showed that despite a marked decrease in the number of normal osteocytes—to one half in the oldest preparations—the periosteum of the pedicled graft survived, being from the 3rd day hyperplastic and showing proliferation of osteoblasts. On the 6th day these changes had become further accentuated and there was callus formation as a layer on the periosteal surface. At the same time regeneration of bone marrow tissue and endosteal callus formation were observed. Internally the corresponding changes occurred later, osteoblastic proliferation not occurring in the Haversian canals until the 6th day and creeping substitution from the 10th day.

In the free cortical grafts all the osteocytes disappeared. Not until the 10th day was there any osteoblastic proliferation and incipient



*Fig 5*

3rd day Autoradiographs of cortical grafts the pedicled one on the left A number of hot spots" and pronounced marginal blackening around the pedicled graft only faint marginal blackening around the free graft × 20

periosteal callus formation and no signs of creeping substitution appeared within the observation period

The injected preparations showed good agreement with the histological findings The pedicled grafts showed on the first day numerous filled vessels extending from the hyperaemic periosteum deep into the graft some vessels debouching on the endosteal surface The older preparations gradually exhibited an increasing number of filled vessels and the graft seemed to be fully vascularized In contradistinction the free grafts had not until the 6th day a single vessel and in the older preparations still only a few vessels peripherally in the graft

Autoradiographically the pedicled cancellous grafts resembled the appearances of a normal trochanter At the site of callus formation there was a more pronounced blackening and in the small well defined necrotic areas there was no blackening The free grafts were hardly visible until periosteal callus formation had set in and the inside of the graft was empty

Autoradiographs of the pedicled cortical 1 day preparation presented itself as normal autoradiography with diffuse blackening of the inside interspersed with numerous rather faint but yet distinctly



Fig. 6

10th day. Autoradiographs of cortical grafts, the pedicled one on the left. The violent blackening around the pedicled graft represents callus. × 20

recognizable centres with a higher activity, the so called "hot spots". Moreover, there was a more pronounced blackened line corresponding to the entire surface of the graft. This surface phenomenon was less marked on the free graft whose inside was empty. On the 3rd day the marginal blackening on the pedicled graft was wider and now there were about ten "hot spots". After this juncture the activity of the pedicled graft greatly increased in the periosteum as well as in the inside and by far exceeded that of the corresponding free grafts which showed blackening only at the sites of the more scanty periosteal callus.

Fluorescence microscopy of the pedicled cortical grafts showed on the 1st day a thin fluorescent streak around 3 vessels in the graft. On the 3rd day there was a more pronounced circle around several small vessels filled with India ink, in the same numbers as the "hot spots" on the autoradiographs of the same section. Not until the 6th day could fluorescence be observed on the surface at the site of the periosteal and endosteal callus, and from that time on the fluorescence accurately corresponded to the newformed bone.

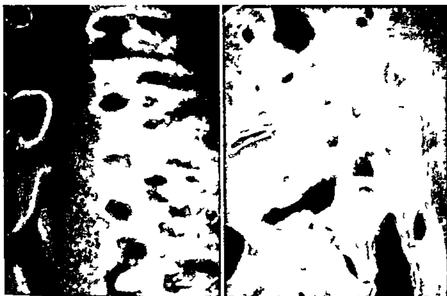


Fig 7

Fluorescence microscopy of pedicled cortical grafts 6th day on the left 3rd day on the right There was no fluorescence of the corresponding free grafts × 125

The free grafts showed no fluorescence until the 10th day when it was apparent in one site of the periosteum corresponding to incipient callus formation

*Group II*

Histological investigation of the cancellous grafts from the 1st 7th week revealed that on the whole the grafts had survived Only 2 preparations exhibited necrosis which did not comprise more than one third of the graft Callus formation was satisfactory but not equally intense in all the preparations although in other respects they looked like normal living bone On the older preparations it was difficult to distinguish newformed bone from the original structure However the newformed bone was somewhat paler and contained larger osteocytes There was normal bone marrow in all grafts

In the cortical preparations there was an even development from the 1st to the 7th week The osteocytes disappeared almost completely from the endosteal half of the graft and gradually most of these cells also disappeared from the subperiosteal part leaving only small areas of normal osteocytes Pronounced osteoclastic absorption took place so



*Fig. 8*

7th week. Histological preparation of pedicled cancellous graft. Normal osteocytes and bone marrow. Periosteal callus. × 125

that towards the end of the experimental period the original graft showed a coarse meshed, almost spongy structure. Concurrently there was marked creeping substitution. Periosteal and endosteal callus formation was very pronounced, eventually surrounding the entire graft. In the most pronounced cases the preparation was transformed into a small ossicle, consisting of a thin layer of newformed compact bone lined with periosteum, enveloping a cavity with ample medullary tissue, loose structured callus, and remnants of the original, greatly substituted graft.

The results found in the last rabbits used for $^{32}$P experiments are presented in the table.

TABLE

*Counts/g/min*

| Cancellous bone | | Compact bone | | Humerus | Blood |
|---|---|---|---|---|---|
| Pedicled | Free | Pedicled | Free | | |
| 1000 | 116 | 649 | 488 | 648 | 461 |

## DISCUSSION

If a soft tissue pedicle is to contribute to preserving the vitality of a bone graft it is mandatory that a reasonable number of vessels enter the bone from the surrounding soft tisues

The blood supply of the long bones has been thoroughly studied by *Lexer* (15) and *Johnson* (13) who have consistently described the following systems

The nutrient arterial system The nutrient artery divides into ascending and descending branches which supply the bone marrow and the inner half to two thirds of the diaphyseal cortical bone

The metaphyseal and epiphyseal system which consists of a large number of small vessels penetrating the bone from muscular and ligamentous attachments dividing profusely in the bone marrow which they supply together with the inner half of the metaphyseal cortical bone

The periosteal system which surrounds the bone in the form of a dense anastomosing network supplying the outer one third to one half of the cortical bone

There are fully sufficient anastomoses between the nutrient arterial system and the metaphyseal system which thus can compensate for each other On the other hand the anastomoses from the periosteal system to the other two systems are scanty This was confirmed by *Trueta & Cavadias* (25) who in cases of medullary nailing found necrosis of the inner half to two thirds of the cortical bone

Our grafts cancellous as well as cortical were obtained from the metaphysis and their blood supply therefore consists partly of metaphyseal and partly of periosteal vessels

The thickness of the muscle pedicle decides the number of metaphyseal vessels which penetrate the graft and thereby the nutrition of its profound part while the periosteal system can be supplied through a more slender pedicle We have tried to preserve a pedicle as thick as possible Thus on the trochanter the pedicle covered the entire periosteal surface while on the ulna it covered only half When considering moreover that in the compact bone there are only a few anastomoses and at that only of capillary size between the individual Haversian systems it is evident that the blood supply of the compact graft is more critical than that of the cancellous graft This presumably affords the explanation of the difference observed between the osteocytes in the cancellous and in the cortical graft

The histological assessment is disturbed by the fact that a long time may elapse until the perished osteocytes disappear from the lacunae. As a rule, however, they can be distinguished from normal osteocytes as their nuclei generally show distinct pyknosis. They are small and stain intensely and uniformly. In the event of karyorrhexis doubt may arise, as a similar phenomenon may be observed as an artefact in normal bones. Thus, the histological evaluation carries some uncertainty. Therefore, the investigations were supplemented by injection of the vessels, autoradiography and fluorescence microscopy.

The injection experiments afforded a convincing impression of the early and marked hyperaemia of the periosteum and the ample vascularization of the pedicled grafts, thus supplementing the histological findings.

In an effort to obtain a quantitative evaluation of the vascularization of the graft, we performed the above-mentioned $^{32}P$ experiment. Considering the short period between the administration of the isotope and the counting, we expected to obtain a result in which the vascularization was the decisive factor. The investigation showed a distinct difference between pedicled and free grafts, but did give an impression of considerable uncertainty. As a result, this method was not used in further case.

The results of autoradiography were largely consistent with the histological findings and the injection experiments, showing a distinctly higher activity of the pedicled grafts. It is well known that a dead bone can also take up $^{45}Ca$. Thus, using experimental conditions comparable to ours, *Ray et al.* (22) by autoradiography of dead bone could obtain a picture which in respect to marginal blackening was like the corresponding living bone. However, the exposure period was 15 times longer. Although the uptake of $^{45}Ca$ cannot be taken directly to be a vital process, there are considerable quantitative differences between dead and living bone.

In one of our younger preparations there was a marginal blackening and an intensity of "hot spots" (Fig. 5) which did not only exceed that of the free graft, but also that of the corresponding normal preparation. This cannot be explained by callus formation, because at that time there was only incipient osteoblastic proliferation. However, there was only unmistakable hyperaemia of the periosteum (Fig. 3) which may perhaps have caused the phenomenon. In that event it might be compared with *Bauer's* (1) finding of the increased uptake of $^{45}Ca$ by bone

tumours sometimes observed long before the lesion is demonstrable by X rays

The fluorescence microscopic findings resembled the autoradiographic results This was only to be expected since—like ⁴⁵Ca—the tetracyclines label the not fully mineralized newformed bone and callus However the tetracycline labelling is more sharply defined and more specific Thus the above-mentioned marginal area showed no uptake of tetracycline (Fig 7) which accurately followed the periosteal callus formation

One factor is worthy of special mention In all phases the pedicled cortical grafts exhibited a strikingly greater osteogenic activity than the cancellous grafts A possible explanation is the above-mentioned more critical blood supply of the cortical bone which involves more widespread necrotic changes and thereby exerts a more potent stimulation for hyperaemia and new bone formation Owing to the somewhat artificial experimental conditions—motivated by the wish to avoid actions from the surrounding structures—the surviving cancellous graft lacks a stimulus and therefore responds only by callus formation on the surface

## SUMMARY AND CONCLUSION

Comparative studies on pedicled and free bone grafts were carried out on rabbits

On the basis of histological investigations injection of vessels autoradiographs and fluorescence microscopy the authors conclude that free bone grafts undergo necrosis while pedicled cancellous grafts survive In pedicled compact bone grafts the majority of the osteocytes disappear but the blood supply and thereby the osteogenetic ability persists

## RESUME ET CONCLUSION

Avec des lapins comme animaux d'essai il a été procédé à des examens comparatifs de greffes osseuses pédonculées et libres

Sur la base d'un examen histologique d'injections vasculaires d'autoradiographie et de microscopie fluorescente il est conclu que les greffes osseuses libres se nécrosent alors que les greffes spongieuses pédonculées survivent Dans les greffes osseuses pédonculées compactes la plupart des ostéocytes disparaissent mais l'approvisionnement des vaisseaux est maintenu et par là le pouvoir ostéogénétique

## ZUSAMMENFASSUNG UND SCHLUSSFOLGERUNG

An Kaninchen als Versuchstiere führte man vergleichende Untersuchungen von gestielten und freien Knochenspangen aus.

Auf Grundlage von histologischen Untersuchungen, Gefässinjektionen, Autoradiographie und Fluoreszenzmikroskopie schliesst man, dass freie Knochenspangen nekrotisieren, während gestielte spongiöse Spangen überleben. In gestielten kompakten Knochenspähnen verschwinden die meisten Osteozyten, aber die Gefässversorgung und damit die osteogenetische Potenz wird beibehalten.

## REFERENCES


1. *Bauer, G. C. H.:* 85Sr and 47Ca in the Study of Bone. Radioisotopes and Bone. Blackwell, Oxford 1962.
2. *Bertelsen, A.:* Experimental Investigation into Post Foetal Osteogenesis. Acta orthop. scand. *15*, 139–181, 1944.
3. *Codivilla, A.:* Über die Behandlung der Pseudarthrosen und der ausgedehnten diaphysären Continuitetstrennungen. Arch. klin. Chir. *92*, 452–478, 1910.
4. *Cole, P. P.:* Pathological Fracture of Mandible. Non-Union Treated with Pedicled Bone Graft. Lancet *1*, 1044–1045, 1940.
5. *Cuneo, & Block:* Technique de osteoplastie et plus specialement de celle du femur. J. Chir. (Paris) *23*, 113–122, 1924.
6. *Davis, J. B. & Taylor, A. N.:* Muscle Pedicle Bone Grafts. Experimental Study. Arch. Surg. *65*, 330–336, 1952.
7. *Farmer, A. W.:* The Use of a Composite Pedicle Graft for Pseudarthrosis of the Tibia. J. Bone Jt. Surg. *34-A*, 591–600, 1952.
8. *Ham, A. W.:* Some Histophysiological Problems Peculiar to Calcified Tissues. J. Bone Jt. Surg. *34-A*, 701–728, 1952.
9. *Hartley, J. & Silver, N.:* Muscle Pedicle Bone Grafts. J. Bone Jt. Surg. *36-A*, 800–809, 1954.
10. *Hellstadius, A.:* On the Ability of Bone Tissue (including "Os Novum") to Survive in Pedicled Bone Grafts. Acta chir. scand. *86*, 85–109, 1942.
11. *Hibbs, R. A.:* An Operation for Stiffening the Knee-Joint. Ann. Surg. *53*, 404–407, 1911.
12. *Hibbs, R. A.:* A Preliminary Report of Twenty Cases of Hip Joint Tuberculosis Treated by an Operation Devised to Eliminate Motion by Fusing the Joint. J. Bone Jt. Surg. *8*, 522–533, 1926.
13. *Johnson, R. W.:* A Physiological Study of the Blood Supply of the Diaphysis. J. Bone Jt. Surg. *9*, 153–184, 1927.
14. *Judet, R.:* Epaule. Fractures du col du femur. Actualités de chirurgie orthopedique de l'hopital Raymond Poincaré. II, 78–104, 1963.
15. *Lexer, E., Kuliga, & Turk:* Untersuchungen über Knochenarterien. Hirschwald, Berlin 1904.
16. *Loe, H.:* Bone Tissue Formation. Acta odont. scand. *17*, 311–427, 1959.

17 *Movin R* Alloplasty of the Hip as Treatment in Suitable Cases of Fracture of the Neck of the Femur and in Sequels of Such Fractures p 16 Thesis Munksgaard Copenhagen 1957

18 *Movin R* Fracture colli femoris Foredrag ved Dansk Kirurgisk Selskabs 357 møde April 1958 Nord Med *61* 651 1959

19 *Movin R* On the Use of Muscle Pedicle Bone Grafts in Fresh Subcapital Fractures of the Femur Joint Meeting of the British Orthopaedic Association and the Scandinavian Orthopaedic Association August 1962 Acta orthop scand In Press

20 *Payr E* Uber osteoplastischen Erzatz nach Kieferresektion (Kieferdefekten) durch Rippenstucke mittels gestielter Brustwandlappen oder freier Transplantation Zbl Chir 35 1065–1070 1908

21 *Phelps A M* Transplantation of Tissue from Lower Animals to Man and a Report of the Case of Bone Transplantation Med Res 39 221–225 1891

22 *Ray R D Stevens J Lyon I & Rowland R E* Uptake of 45Calcium and 14Carbon Labelled Proline by Dead and Living Bone Radioisotopes and Bone Blackwell Oxford 1962

23 *Reichel P* Zur Behandlung schwerer Formen von Pseudarthrosis Arch klin Chir *71* 639–651 1903

24 *Spalteholz K W* Uber das Durchsichtigmachen von menschlichen und tierischen Praparaten Leipzig 1914

25 *Trueta J & Cavadias A X* Vascular Changes Caused by the Kuntscher Type of Nailing An Experimental Study in the Rabbit J Bone Jt Surg *37–B* 492–505 1955

26 *Watson-Jones R* The Repair of Skull Defects by a New Pedicle Bone Graft Operation Brit med J *1* 780–781 1933

27 *Woodhouse C F & Farouk S I* The Transplantation of Living Bone Grafts J int Coll Surg *38–2* 329–340 1962

Acta orthop. Scandinav. XXXVI, 294–299, 1965

Institute for Experimental Research in Surgery
(Director: H. H. Wandall, M.D.), University of Copenhagen, and
Surgical Department A (Head: R. Mosin, M.D.), Frederiksberg Hospital,
Copenhagen, Denmark

# HEALING OF MUSCLE PEDICLE BONE GRAFTS

## *An Experimental Study*

*By*

SÁNDOR MEDGYESI

A muscle pedicle graft receives its blood supply through a soft tissue pedicle, so that grafting over a fairly short distance ought to be compatible with the survival of some of its cells. The graft may be compact or cancellous, and the pedicle usually consists of a muscle and tendon or subcutaneous tissue and skin, depending on the donor site.

In a previous paper (1) the reported clinical and experimental studies on muscle pedicle bone grafts were reviewed. Only a few experimental studies have been published (2, 3, 4 and 7), and the results have differed. Our results are among the positive ones, and the present study marks a further step forward in the series. This time the transplantation was performed in a way which eliminated the osteogenetic activity of the recipient site in order to assess the role of the graft itself in the healing process.

The method was as follows. The experimental animals were white rabbits weighing 2.5–3.5 kg. The rabbits were mature, but in some of them the epiphyseal cartilage could be discerned. The operation was carried out under Nembutal anaesthesia. A graft $10 \times 5 \times 5$ mm was removed from the greater trochanter on both sides. The pedicle consisted of half the gluteus medius and minimus, which were dissected to a length of 1 cm. From the iliac crest a somewhat larger piece of bone was removed, freed entirely and denuded of muscle tissue. The pedicle grafts and the pieces of bone were tied together with a silk

Aided by a grant from the Danish Science Foundation.



*Fig 1*

A 4 week old preparation Haematoxylin eosin staining × 225
The preparation is from the middle of the pedicle graft The lacunae contain living osteocytes and there are living osteoblasts on the surface of the trabeculae

suture spongiosa facing spongiosa Thereafter the tied bones were isolated by polyethylene foil 0 05 mm thick to prevent possible in growth of vessels from the surrounding structures The bones were cut with a rotating saw A total of 13 rabbits had this type of operation Another 2 were treated in fundamentally the same way except that the muscle pedicle graft was removed from the iliac crest and the free graft from the trochanter The rabbits were killed from 1–5 weeks after the operation one 12 weeks after The specimens were studied by gross inspection and histologically after decalcification with formic acid and staining with haematoxylin-eosin and van Gieson

## RESULTS

Out of the 30 grafts two were infected (abscess formation) and 2 could not be examined histologically Among the 26 preparations studied the entire pedicle graft was alive in 15 (Fig 1) However in these grafts too there was a narrow rim of empty lacunae close to the cut edge In [illegible] grafts parts of the bony tissue had undergone aseptic



Fig 7

A 2 week old preparation Haematoxylin eosin staining × 75
At the bottom a segment of the pedicle graft and at the top the dead free graft in its entire thickness A net of ample endosteal callus extends from the pedicle graft attaching itself to the trabeculae in the free graft

necrosis which involved up to 75 per cent of the graft indicating serious disturbance of the blood supply In 4 grafts there were apparently no living osteocytes However one of these grafts (a 2 week old specimen) was surrounded by so much new formed bone that it was attached to the free graft by callus Callus formation could be observed between the two grafts as early as one week after the grafting and it increased during the subsequent weeks The callus included subperiosteal and pronounced endosteal proliferation of osteoblasts



*Fig 3*

A 4 week old preparation Haematoxylin eosin staining × 160
A segment from the inside of the free bone There is vascular ingrowth and newformed bony tissue on the surface of the dead trabeculae

and matrix formation followed by deposition of calcium The endosteal callus was of a spongy nature but the new trabeculae were more densely arranged than seen in the trochanter and iliac crest (Fig 2) In 23 cases there was bony union At the end of 3–4 weeks there was ingrowth of vessels and scanty new bone formation inside the free bone grafts (Fig 3) The newformed bone was in the form of thin linings on the surface of the old trabeculae

## DISCUSSION

Upon transplantation of fresh autogenous bone the majority of the osteocytes and the included soft parts undergo necrosis before revascularization has taken place If the donor site is favourable a slow revascularization sets in followed by new bone formation in the graft and healing occurs Thus the most important factors are the mechanical properties of the graft and its inductor function whereas it probably has no major active share in osteogenesis Where the donor site has a poor blood supply and little osteogenetic ability the result

may be poor healing of the graft Consequently it is a reasonable idea to find a graft whose vitality is wholly or partially preserved and which can take active part in the healing process Interest in such grafting material has been evident in this country as well as abroad (5 6)

In a previous study (1) we demonstrated that considerable parts of the muscle pedicle grafts survive and form callus However the question remained whether it was sufficient to tie the graft to a site with little osteogenetic ability The author therefore selected a surgical method involving polyethylene isolation which appears to have afforded sufficient guarantee that the healing can be ascribed exclusively to the pedicle grafts Although a few cells may have survived in the free grafts their presence was entirely dependent upon nutrition *via* the pedicle grafts

Union occurred in 23 cases (88 per cent) also in cases where part of the pedicle graft was necrotic In one case all the osteocytes were apparently necrotic A possible explanation is that the graft preserved part of its blood supply or that a rapid revascularization took place sufficient to supply the proliferating osteoblasts with nutrition

It should be emphasized that in some of the older preparations there was vascular ingrowth and new bone formation inside the free bone grafts In these cases the pedicle grafts have not merely survived but also been able to supply part of the other bone graft with nutrition

The grafts were cancellous bone grafts with a good thick pedicle Something entirely different seems to apply to compact grafts (1) which show poorer survival despite a great osteogenetic activity

SUMMARY

A series of 30 muscle pedicle grafting operations on 15 rabbits is reported The object was to investigate whether the grafts were able to heal unaided Therefore the recipient site was cut off from blood supply and isolated

Out of the 26 cases 22 grafts survived wholly or partially

In 23 cases bony union had taken place

There was a certain revascularization and new bone formation at the recipient site *via* the muscle pedicle grafts

RESUME

Rapport sur un materiel d observation de 30 greffes d operation de pedicules musculaires chez 15 lapins Le but de cette investigation etait

de voir si les greffes peuvent vivre d elles memes sans aide C est pour quoi le site recepteur a ete coupe de l apport de sang et isole

Sur ces 26 cas 22 greffes ont survecu entierement ou partiellement Dans 23 cas la soudure osseuse s etait faite

Une certaine vascularisation s est etablie et il y avait une nouvelle formation osseuse dans le site recepteur sur la base des greffes de pedicules musculaires

## ZUSAMMENFASSUNG

Uber ein Material von 30 gestielten Muskel Knochenverpflanzungen an 15 Kaninchen wird berichtet Das Ziel der Untersuchung war her auszufinden ob das Transplantat von selbst einheilen konnte Es wurde daher der Empfangersitz von der Blutzufuhr abgeschnitten und isoliert

Von 26 Transplantaten überlebten 22 vollstandig oder teilweise

In 23 Fällen hatte eine knocherne Vereinigung stattgefunden

Eine gewisse Revaskularisierung und Knochenneubildung am Emp fangersitze uber das Muskelstiel Transplantat wurde gesehen

## REFERENCES


1 *Baalsgaard K* & *Medgyesi S* Muscle Pedicle Bone Grafts Experimental Study Acta orth p Scandinav In Press

2 *Davis J B* & *Taylor A* Muscle Pedicle Bone Grafts Experimental Study Arch Surg 65 330–336 1952

3 *Hartley J* & *Silver N* Muscle–Pedicle Bone Grafts J Bone Jt Surg 36-A 800–809 July 1954

4 *Hellstadius A* On the Ability of Bone Tissue (including Os novum ) to survive in Pedicled Bone Grafts

5 *Judet R* Epaule Fractures du col du femur Actualites de chirurgie orthopedique de l'hopital Raymond Poincare II 78–104 1963

6 *Movin R* On the Use of Muscle–Pedicle Bone Graft in Fresh Subcapital Fractures of Femur Acta orthop Scandinav 33-4 182 1963

7 *Woodhouse Ch F* *Farouk S I* & *French D* The Transplantation of Living Bone Graft J Int Coll Surg 38 2 329 340 1962

Acta orthop. Scandinav. XXXVI, 300–313, 1965

Department of Orthopaedic Surgery, University of Gothenburg, and
Department of Anatomy, University of Michigan

# STUDIES ON SOME PHYSICAL PROPERTIES OF INFANT COMPACT BONE[1]

By

CARL HIRSCH and F. GAYNOR EVANS

## INTRODUCTION

Tensile stress and strain of bone have been investigated less extensively than its other stress-strain characteristics. The probable reason for this is the technical difficulties involved in preparing and testing bone specimens in pure tension. The advantage of testing specimens in pure tension (or compression) is that the ultimate breaking stress (strength) of the specimen is much easier to calculate than when the specimen is tested in shearing or in bending.

When a specimen is tested under a pure stress (tension or compression) there is only one type of force involved and it is uniformly distributed over the cross sectional area of the specimen. Thus the ultimate breaking stress of the specimen can be easily computed from the formula $S = \frac{P}{A}$ in which S is stress, P is the breaking load and A is the cross sectional area of the specimen at the fracture site. When, on the other hand, a specimen is tested under bending its cross sectional area is subjected to a combination of tensile, compressive and shearing stresses which are not uniformly distributed over the cross sectional area of the specimen. Consequently, it is difficult to compute the ultimate breaking stress. Similar difficulties are encountered if a specimen is tested under shear. Diagrams showing the stress distribu-

[1] This research was supported by the Swedish State Medical Research board, the University of Gothenburg, Stille Company, Stockholm and (in part) by USPHS Fellowship AF 13 503 (AT 633) and Research Grant A 03865-05 from the National Institutes of Health, USPHS.



Fig 1

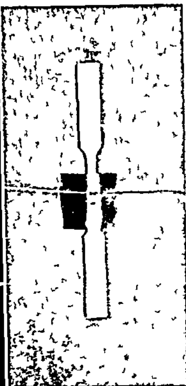


Fig 2

*Fig 1* Femur of a female 2 days old. The cortical bone available for making tensile test specimen is seen between the 2 markers

*Fig 2* Tensile specimen with strain gage.

tion under the above conditions can be found in most textbooks on strength of materials

## MATERIALS AND METHODS

The material used in the present investigation was obtained from fresh autopsy limbs of infants and children of various ages. Because of the small size of the bones of infants, especially those of newborns, only the femur was large enough for our purpose. The autopsy limbs were kept separate in containers in a deep freezer at −[illegible] C until the test specimens were made.

At first small spindles, similar to those used by [illegible] *et al.* ([illegible]) in their study on some physical properties of the bone of irradiated beagle dogs, were tried. However, because of the small amount of cortical bone in the femur of infants (Fig. 1), these had to be abandoned in favor of flat specimens. Flat test specimens are also much easier to make than spindles.

The specimens used in the present study were standardized as to shape (Fig. 2) [illegible]

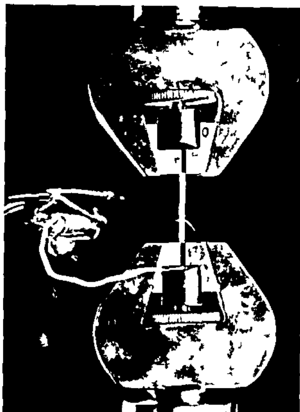


*Fig 3*
Close up view of jaws and specimen ready for testing The object at the left is the lead from the strain gage to the recording bridge

but their size varied with the amount of cortical bone available The minimal size specimen successfully tested especially if tensile strain was also determined was approximately 25 mm long (with a reduced middle region 5 mm long and 1.3 mm wide) 1 mm thick and 3 4 mm wide at the gripping ends The long axis of the specimen coincided with that of the intact bone Reducing the cross sectional area of the middle part of the specimen concentrates the stress in that area where the tensile strain was also measured A factor limiting the size of the specimen was the necessity that it be absolutely straight to ensure that the tensile force applied to it during a test was uniformly distributed over the cross sectional area of the specimen In preparing the specimens care was taken to make as large a radius of curvature as possible at the fillet (junction between the reduced and non reduced parts) to minimize the stress concentration in that region

After the specimens were made they were put into separate vials and returned to the deep freezer Shortly before testing the specimens were removed from the freezer and allowed to thaw so that they would be moist when tested Preventing the specimens from drying is important because *Wertheim* (1847) *Rauber*

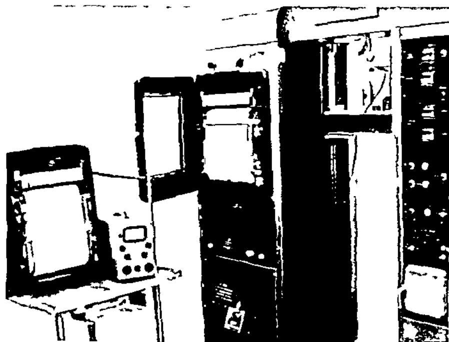


*Fig 4*
Testing and recording apparatus

(1876) *Hulsen* (1896) *Evans & Lebow* (19 1) *Dempster & Liddicoat* (195?) *Lease & Evans* (1959) *Dempster & Coleman* (1961) *Evans* (in press) and *Sedlin & Hirsch* (in press) have all shown that drying affects the physical properties of bone

Because of the thinness of the specimens (1 mm or less) great difficulty was encountered in holding them so they would not slip when loaded in the testing machine The moist condition of the specimens also made them more d fficult to hold The kind of jaws used in earlier studies of the tensile strength of specimens from the long bones of adults (*Evans & Lebow* 1951) were not satisfactory for such small specimens so new jaws had t be designed. These jaws (*Fig* 3) consisted of two wedge shaped chucks with rough face and a thumb screw to exert additional f rce on the chucks and thus tighten th ir grip n the expanded en ls of the speci mens The thumb screws also aided in aligning the pecimens properly in the jaws

The specimens were l aded to failure under i ect tension In an Instron Tensile Te ting Instrument Mo lel TT BM (Fig 4) calil rated t an accuracy of ± 1 per cent Th specimen were l a led in the directi n f their l ng axi at a con tant peed f 0 1 cm/min and t room temper tu e f 0 ?? C an l a humidity of f per cent. When mount ng the specimen in th t ting machine great c re wa taken to have the long ax s f the specimen in r f t vertical alignment with the a lapter holding the jaw n the In tron machine Thi wa neces ary o tl at the ten ile f r e would be un forml di tril uted o r tl e s secti n area f the specimen when it was te ted

Attempts were made at first, when small spindles were being tried, to measure the tensile strain with a mechanical extensometer especially designed for the purpose. The extensometer consisted of two flexible cantilevers on which electrical strain gauges were bonded and pieces of safety razor blades between which the specimens were placed. This method proved to be unsatisfactory because of the difficulty of properly attaching the extensometer to the specimen and was given up.

The tensile strain occurring in a specimen during a test was finally measured by cementing a strain gage directly to the reduced area of the specimen (Fig. 2). Budd Metafilm Foil Strain Gages (Type C12 LXL–M50A) 3 mm long with a gage factor of 2.01 ± 1 per cent and a resistance of 120 ± 0.5 ohms were used. A gage was bonded to the specimen with Eastman 910 cement after a small area of its surface had been swabbed with ether in order to dry it so that the gage would stick. The extent to which this may have influenced the results of the test is unknown at present. The change in the electrical resistance of the gage produced by elongation of the bone specimen during a test was recorded by a Hottinger Strain Gage Bridge (Model KWS/T 5) and a Speedomax recorder (Fig. 4). A paper speed of 30 cm/min was used. Before each test the bridge was calibrated in five steps. After a test the dimensions of the specimen at the fracture site were measured under a microscope equipped with a micrometer ocular. Two measurements of the width and thickness were made and the cross sectional area computed (in mm²) from the average value of the two measurements. The ultimate tensile stress (strength) was then calculated from the formula $S = \frac{P}{A}$ discussed previously. The tensile strain occurring in a specimen during a test was recorded as per cent elongation, the ultimate tensile stress (strength) in kg/mm².

During a test two curves—one for load (stress) and a second one for strain were automatically drawn on separate papers. From these curves the tangent modulus of elasticity of a specimen, which is a measure of its stiffness, was computed in kg/mm².

In this study bone is being treated as a material rather than as a structural unit. The conditions under which the specimens were tested have been deliberately simplified by comparison with those that would be expected for bone in a living body.

## RESULTS

The results of the tests can be divided into two groups—infant and child—on the basis of the age of the individual from whom the specimens were obtained. The specimens in the "infant" group came from individuals ranging up to six months of age while those in the "child" group were all from a fourteen year old boy. The values for the physical properties determined for these specimens as well as data on the individuals from whom the specimen came are given in Table 1.

A tendency toward an increase in ultimate tensile stress (strength) with the advancing age of the individual was noted with a rather marked separation between the strength values for specimens in the two groups.

TABLE 1

*Tensile Stress, Strain and Modulus of Elasticity of Compact Bone of Infants and Children*

| Bone and specimen | Thickness (mm) | Breaking load (kg) | Ultimate tensile stress (kg/mm²) | Tensile strain (% elongation) | Modulus of elasticity (kg/mm²) | Specimen data |
|---|---|---|---|---|---|---|
| Femur [illegible]-1 | 1.14 | 15.00 | 13.16 | 1.90 | 1281 | Newborn female |
| Femur 3-1 | 1.68 | 10.50 | 9.82 | [illegible] | 901 | 1 day old male |
| [illegible]3 | 1.65 | 14.50 | 8.73 | 2.00 | 703 | |
| Femur 3-1 | 1.54 | 14.[illegible]0 | 9.42 | 0.50 | 1701 | 1 day old female |
| Femur [illegible]1 | [illegible]0 | 12.[illegible]0 | 5.68 | 1.00 | 739 | 2 day old male |
| Femur [illegible]-1 | 1.97 | 10.50 | 9.90 | 1.18 | 800 | 2 day old sex? |
| Femur 9-1 | 1.45 | 10.50 | 11.38 | | | 1 week old female |
| 9-2 | 1.36 | 10.00 | 11.76 | 1.60 | 1311 | |
| Femur [illegible]1-1 | 1.73 | 10.50 | 6.07 | 1.00 | 803 | 2 month 5 day old male |
| Femur 10-1 | 1.30 | 15.25 | 11.73 | 2.31 | 908 | 6 month old sex? |
| 10-2 | 1.46 | 16.50 | 11.30 | 1.76 | 1164 | |
| 10-3 | 1.48 | 16.25 | 10.98 | [illegible] | 820 | |
| Femur 1[illegible]-1 | 1.30 | [illegible]00 | 1[illegible] | 1.80 | 1154 | 14 year old male |
| 12-2 | 1.33 | [illegible]8.00 | [illegible]0.44 | 1.72 | [illegible]273 | |
| 12-3 | 1.22 | [illegible]50 | 18.44 | 1.41 | [illegible]251 | |
| 1[illegible]-4 | 1.70 | [illegible]5.00 | 14.70 | [illegible] | [illegible]000 | |

## ZUSAMMENFASSUNG

1. Eine Methode zur Bestimmung der äussersten Dehnungsbeanspruchung (Stärke), der Dehnungsspannung (Prozent Verlängerung) und der tangentialen Grösse der Elastizität von kleinsten Proben des kompakten Knochens des Femurs von Kindern (Neugeborenen – 6 Monate alten) und von einem 14 jährigen Knaben wird beschrieben.

2. Die durchschnittlich grösste Dehnungsbeanspruchung der Proben von Kindern war grosser als die, welche von anderen Untersuchern fur frische Proben von Femuren Erwachsener berichtet wurde. Die Variationsbreite der Dehnungsbeanspruchung von kindlichen Proben glich den Ergebnissen Raubers für frische Proben von Knochen Erwachsener. Die durchschnittlich grösste Dehnungsbeanspruchung von Proben des Femurs eines 14 jährigen Knaben war grosser als die irgend welcher Proben des Knochens Erwachsener ohne Rucksicht auf den Prufungszustand des letzteren (frisch oder aufbewahrt, nass oder trocken).

3. Die durchschnittliche Dehnungsspannung von Proben kindlicher Femuren ist grosser als die von frischen Proben der Knochen Erwachsener. Proben von Kindern habe jedoch eine geringer Variationsbreite der Dehnungsspannung.

4. Der Durchschnitt und die Variationsbreite des tangentialen Masses der Elastizität von kindlichen Proben sind bedeutend geringer als die von entsprechenden Proben der Knochen Erwachsener.

5. Eine Durchsicht der erhaltlichen Litteratur wies keine fruheren Untersuchungen über die Dehnungsbeanspruchung, die Dehnungsspannung und das tangentiale Mass der Elastizität von kindlichem kompaktem Knochen auf.

## REFERENCES


*Carothers, Charles O., Smith, Frank C. & Calabrisi, Paul*: The Elasticity and Strength of Some Long Bones of the Human Body. Naval Medical Research Institute Project NM 001 056 02 13, 1949.

*Dempster, Wilfrid T. & Liddicoat, Richard T.*: Compact Bone as a Non Isotropic Material. Amer. J. Anat. *91*: 331–362, 1952.

*Dempster, Wilfrid T. & Coleman, Robert F.*: Tensile Strength of Bone Along and Across the Grain. J. appl. Physiol. *16*: 355–360, 1961.

*Evans, F. Gaynor*: Stress and Strain in Bones. 245 pp. Thomas, Springfield, Ill., 1957.

*Evans, F. Gaynor*: Significant Differences in the Tensile Strength of Adult Human Compact Bone. First European Bone and Tooth Symposium. Pergamon Press, Oxford (in press).

*Evans, F. Gaynor & Lebow, Milton*: Regional Differences in Some Physical Properties of the Human Femur. J. appl. Physiol. *3*: 563–572, 1951.

*Hulsen K K* Specific Gravity Resilience and Strength of Bone Bull Bi l Lab St Petersburg *1* 7-35 1896 (in Russian)

*Lease Glenn O D & Evans F Gaynor* Strength of Human Metatarsal Bones Under Repetitive Loading J appl Physiol *14* 49-51 1959

*Rauber August A* Elasticitat und Festigkeit. Engelmann, Leipzig 1876

*Sellin E & Hirsch C* Physical properties of bone Acta orth p Scand (in press)

*Taysum David H., Evans F Gaynor Hammer W M Jee W S S Rehfeld C F & Blake L W* Radionuclides and Bone Strength in Beagles in Some Aspects of Internal Irradiation pp 145-162 Pergamon Press Oxford 1962

*Wertheim M G* Memoire Sur l'Elasticite la Cohesion des Principaux Tissus du Corps Humain Ann Chim. et de Phys 3e serie XXI 385-414 1847

Acta orthop. Scandinav. XXXV, 314–328, 1965

From the Department of Orthopaedic Surgery (Head: Prof. Carl Hirsch, M.D.),
University of Gothenburg, Sweden

# THE EFFECT OF FORWARD LEANING ON LUMBAR INTRADISCAL PRESSURE

*By*

A. NACHEMSON

Many calculations have been made of the load on the lower inter-vertebral discs in the forward bending position (*Bradford & Spurling* 1947, *Waris* 1949, *Mathias* 1956, *Perey* 1957). In this position carrying of weights has been said to increase the load on the disc by five (*Waris* 1948) to ten (*Bradford & Spurling* 1947, *Perey* 1957) to twenty (*Mathias* 1956) times the weight carried.

No measurements of the intradiscal pressure in the forward leaning position have been reported. This study presents data of the intradiscal pressure and to what extent it increases by forward leaning with or without weight bearing.

## METHODS

The method used for intradiscal pressure measurements *in vivo* has previously been described (*Nachemson & Morris* 1963, 1964) (Fig. 1).

In the present study the eight patients were first measured in an upright sitting position. Two of them were also examined standing. The interspace to be measured was localized by a roentgen image intensifier apparatus. After three consecutive measurements in the upright position the patient was told to lean forward twenty degrees, i.e. to flex in his hips and hold his back straight. The forward angulation was measured (Fig. 2). Measurements were made and again repeated with the patient holding five and ten kilogram weights respectively in his hands in the same forward leaning position.

It is important to hold the pressure transducer horizontal during the measurements. The guide needle and also the transducer with the measuring needle therefore have to be inserted horizontally when the patient is sitting in an upright position. The needle with the pressure sensitive membrane, however, will allow bending of twenty degrees without impairing the results (*Nachemson* 1960). Technical circumstances thus make measurements with forward leaning positions exceeding twenty degrees practically impossible with the present method.

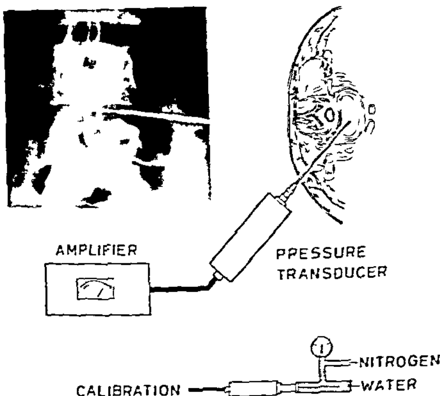



*Fig 1*
Schematic drawing of the method used for intradiscal pressure measurement *in vivo*

### MATERIAL

Pressure measurements were made in a roentgenographically n rmal third r f urth lumbar disc in e ht patients admitted t the h pital f r l w back pain r sciatica (Table 1 In all ca es the nucleog aphy perf rmed after c mpletion f the mea urements was normal. In some in t n es th ries f mea urements wa inter rupted becau e of the patient d s mf rt T b

### RESULTS

In Table 2 are shown the pressures obtained when measurements were made in the forward leaning position of ten and twenty degrees with and without additional loads of five and ten kilograms in each hand The pressur s btained in the sitting position re of the same magnitude as those previously reported achems n & Morris 1964)

When the pati nts leaned forward 2( d gre s values ranging f

TABLE 1
*Summary of Data on Subjects*

| Case no. | Age yr | Sex | Weight kg | Height cm | Body structure | Disc Level | Disc Condition | History |
|---|---|---|---|---|---|---|---|---|
| 1 | 45 | M | 75.0 | 175 | moder. obese | L3 | normal | Low back pain 6 mo. Back to work 4 w. after discharge |
| 2 | 43 | M | 77.0 | 173 | muscular | L3 | normal | Op. hernia L5, 1962. Low back pain > 1 year. Back to work 6 w. after discharge |
| 3 | 22 | F | 67.0 | 163 | moder. obese | L3 | normal | Low back pain 6 mo. Back to work 3 mo. after discharge |
| 4 | 44 | M | 76.8 | 173 | well developed | L3 | normal | Sciatica 3 mo. Op. hernia L4 2 w. after discometry |
| 5 | 41 | M | 76.2 | 186 | well developed | L3 | normal | Low back pain 2 mo. Back to work 3 w. after discharge |
| 6 | 49 | M | 94.0 | 183 | obese | L4 | normal | Sciatica 2 mo. Myelogram neg. Back to work 2 mo. after discharge |
| 7 | 35 | M | 65.7 | 179 | slender | L3 | normal | Low back pain 4 mo. Back to work 2 w. after discharge |
| 8 | 43 | M | 74.0 | 176 | well developed | L4 | normal | Low back pain 2 mo. Back to work 3 w. after discharge |

TABLE 2

*Results Obtained with Subjects in the Sitting Position*

| Case | [illegible] | [illegible] | [illegible] kg (W) | [illegible] In kg/cm | [illegible] kg | Forward leaning 10-20 degrees In kg/cm | Forward leaning 10-20 degrees L kg | Forward leaning 10-20 degrees 5 kg each hand In kg/cm | Forward leaning 10-20 degrees 5 kg each hand L kg | Forward leaning 10-20 degrees 10 kg each hand In kg/cm | Forward leaning 10-20 degrees 10 kg each hand L kg |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | [illegible] | 18.0 | 42.8 | 12.1 | 147.6 | 17.6 | 210.6 | 20.3 | 243.0 | | |
| 2 | [illegible] | [illegible] | [illegible] | 11.3 | 151.5 | 14.1 | [illegible] | 16.9 | 228.3 | 18.7 | 252.5 |
| [illegible] | 1.3 | 14.4 | [illegible] | 11.5 | [illegible] | 15.8 | [illegible] | | | | |
| [illegible] | 1.3 | [illegible] | [illegible] | 12.7 | [illegible] | 15.8 | 170.6 | 23.1 | 249.5 | 27.3 | 294.8 |
| [illegible] | 1.3 | [illegible] | 43.4 | 10.6 | 153.5 | [illegible] | 179.0 | 15.4 | [illegible] | | |
| [illegible] | 1.4 | [illegible] | [illegible] | 11.4 | [illegible] | 16.2 | [illegible] | 18.7 | 267.5 | 23.5 | 336.0 |
| | 1.3 | [illegible] | 37.4 | [illegible] | 140.1 | 13.4 | [illegible] | | | | |
| [illegible] | 1.4 | [illegible] | [illegible] | 10.6 | 140.6 | [illegible] | [illegible] | 13.7 | [illegible] | 16.2 | 213.8 |

— Forward leaning of 10 degrees

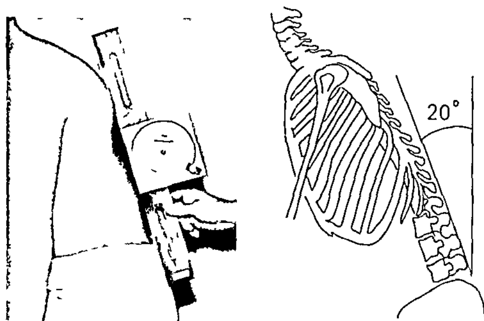



*Fig 9*
Method of estimating the angle of forward leaning The protractor has a water level that can be preset at desired angle In the fig this angle is 20

13 to 18 kg cm were recorded All individuals showed higher pressures compared to the upright sitting position This increase averaged 30 per cent When holding weights of 5 and 10 kilograms in each hand the values rose (19–27 kg cm )

The tables also indicate the load on the whole discs These values are obtained by dividing the pressure by 1 5 and then multiplying this by the cross section area of the disc (*Nachemson* 1960 *Nachemson & Morris 1964*)

The total load on the third and fourth lumbar discs in the forward leaning position of 20 degrees was between 180 and 230 kilograms With 10 kilograms in each hand loads of 250–340 kilograms were noted

## DISCUSSION

### *Sitting Position*

In an earlier presentation it was demonstrated that the load (P) on the L III or L IV level in the upright sitting position is related to the body weight (W) above the level measured This weight (W) was calculated according to *Ruff*s (1945) data which stated that approxi

TABLE 3
Results Obtained with Subjects in the Standing Position

| Case No. | Disc level | Disc area cm | Body weight above disc kg (W) | Pressure Pn kg cm | Total load P kg | Forward leaning 10-20 degrees Pn kg cm | Forward leaning 10-20 degrees P kg | Forward leaning 10-20 degrees kg each hand Pn kg cm | Forward leaning 10-20 degrees kg each hand P kg | Forward leaning 10-20 degrees 10 kg each hand Pn kg cm | Forward leaning 10-20 degrees 10 kg each hand P kg |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | L-4 | 20.6 | 55.5 | 9.4 | 136.1 | | | 17.5 | 250.4 | 19.7 | 280.3 |
| 8 | L-4 | 19.[illegible] | 43.7 | 6.0 | 79.[illegible] | 9.7* | 128.7* | 11.5 | 152.5 | 13.7 | 182.[illegible] |

* Forward leaning of 10 degrees

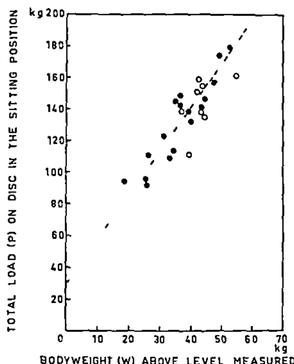



*Fig 3*

**Relation between total load (P) on normal lumbar disc and calculated part of body weight above that level (W) sitting position The slope was determined by means of regression The values obtained in the present series are represented by circles results previously reported by black dots**

mately 60 per cent of the body weight was above the center of L V vertebra with a decrease of 2 per cent for each lumbar vertebra upwards (i e above L IV disc 59 per cent L III disc 57 per cent)

The relation between body weight and load on the disc (L II III and IV) can be written

(1) $$P_{sitting} = P_0 + kW$$

When the patient is sitting the factor k was found to be approximately 2 8 (Fig 3) $P_0$ denotes the intrinsic pressure of the disc which is approximately 30 kg in this position

The observations made on the load in the upright sitting position in the present series have supported the earlier demonstrated equation (1) (Table 2 Fig 3)

Any value of the load on the lower lumbar interspaces in the for

ward leaning position based on theoretical calculations only is apt to have several inherent errors In the present study it has been demonstrated that the initial load for example is much higher than was previously thought

In the calculations made by previous authors (*Bradford & Spurling* 1947 *Morris et al* 1961) on the load on the lumbar discs in the forward bending position the lengthening of certain lever arms were considered These distances can only be approximately estimated due to the lack of determinations of the location of the line of gravity for the upper part of the body in the forward leaning position

On forward bending with or without weight bearing it is however obvious from the results that a certain amount of load must be added to the disc because of the lengthening of some lever arms The center of gravity moves forward and the arms are held at a variable distance from the disc These lever arms should be approximately proportional to the sin of angle of forward bending ($\alpha$) and thus the added load also should be approximately proportional to sin $\alpha$ (Fig 2)

In the sitting and forward leaning position the total load (P) on the third or fourth disc can be approximately expressed by the following equation

(2) $$P_{sitting} = P_0 + kW + k_1 W \sin\alpha$$

TABLE 4

*Values for $k_1$ Derived from Table 2 According to the Equation*

$P_{sitting} = P_0 + k W + k_1 W \sin\alpha$

| Case no | k | | | Case no | k | | |
|---|---|---|---|---|---|---|---|
| 1 | 4 4 | 3 9 | | 5 | 3 6 | 4 8 | |
| 2 | 2 5 | 2 6 | 2 0 | 6 | 3 6 | 3 6 | 4 8 |
| 3 | 3 2 | | | 7 | 3 5 | | |
| 4 | 4 1 | 4 6 | 4 8 | 8 | 3 8 | 1 9 | 2 2 |

Mean 3 6

Solving for $k_1$ using the results shown in Table 2 will give $k_1 \approx 3\ 6$ (range 1 9–4 8) Each specific $k_1$—value is shown in Table 4 When solving the eq (2) $P_0$ was given the value 30 kg k the value found in the upright sitting position in each case (2 1–2 9) W the body weight above the level measured and $P_{sitting}$ the result obtained

The increase of load on the discs resulting from forward leaning of 10–20 degrees in the sitting position varies somewhat in diff

TABLE 5

*Comparison of Pressure Values for Sitting and Standing Positions. Old and New Series*

| Case no | Disc level | Disc area cm | Sitting position: Pressure kg/cm $P_w$ | Sitting position: Total load kg $L$ | Standing position: Pressure kg/cm $P_n$ | Standing position: Total load kg $L$ | Body weight alone kg | Decrease in load from values in sitting | Sex | Age yr | Weight kg | Height cm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Old series* | | | | | | | | | | | | |
| 8 | L-4 | 17.6 | 11.8 | 139.0 | 8.8 | 103.9 | 39.2 | 25 | M | 4[illegible] | 6[illegible] | 1[illegible]3 |
| 15 | L-3 | 19.9 | 11.8 | 157.2 | 7.4 | 97.5 | 47.5 | 38 | M | [illegible] | 83.3 | 179 |
| 16 | L-4 | 21.3 | 9.9 | 145.8 | 8.6 | 121.4 | 44.5 | 17 | M | 52 | 75.2 | 17[illegible] |
| 17 | L-3 | 13.8 | 15.3 | 140.8 | 9.[illegible] | 8[illegible] | 43.3 | 37 | F | 35 | 76.0 | 160 |
| 18 | L-3 | 15.7 | 13.7 | 14[illegible].9 | 8.2 | 86.4 | 36.5 | 3[illegible] | M | 34 | 64.1 | 173 |
| 19 | L-3 | 20.6 | 13.0 | 179.2 | 10.9 | 150.4 | 53.2 | 16 | M | 37 | 93.3 | 186 |
| *Present series* | | | | | | | | | | | | |
| 1 | L-3 | 18.0 | 12.3 | 147.6 | 10.[illegible] | 12[illegible].4 | 4[illegible].8 | 17 | M | 45 | 75.0 | 175 |
| 2 | L-3 | [illegible] | 11.3 | 151.5 | 7.0 | [illegible] | 43.9 | 37 | M | 43 | 77.0 | 173 |
| 6 | L-4 | 21.4 | 11.4 | 16[illegible].6 | 9.4 | 136.1 | 55.5 | 16 | M | 49 | 94.0 | 183 |
| 8 | L-4 | 19.8 | 10.[illegible] | 140.6 | 6.7 | 93.1 | 43.7 | 37 | M | 43 | 74.0 | 176 |

individuals One reason for this could be the individual variations in the lengthening of the lever arms anterior to the spine

By using results from measurements in eight individuals the following mean values of the constants in eq (2) are obtained

$$P_0 = 30 \text{ kg}$$
$$k = 2\ 8$$
$$k_1 = 3\ 6$$

With these constants the eq (2) holds approximately for forward leaning of ten and twenty degrees in the sitting position

In the upright sitting position several authors have registered muscular activity in the sacrospinalis group of muscles (*Akerblom* 1949 *Schobert* 1962) The forces excerted by these muscles have been said to balance the body against gravitational forces The results obtained of the intradiscal pressure and of the load on the lumbar discs are higher than would be expected if these forces alone were responsible for the load on the disc With all probability other forces too act on the lumbar spine Whether these should be discussed in terms of ligamentous forces or muscular forces other than those excerted by the erector trunci or some unknown mechanism still has to be revealed

The results reported in the present study demonstrate the increase resulting from added load in the forward leaning position Earlier calculations (*Bradford & Spurling* 1947 *Waris* 1949 *Mathias* 1956 *Perey* 1957) on the effect of weight carrying give values that are higher than those measured

The load relieving effect of an increased abdominal pressure demonstrated by *Bartelink* 1957 *Davis* 1959 *Morris et al* 1962 and *Eie & Wehn* 1962 is one mechanism that reduces the total amount of load on the lumbar discs

### *Standing Position*

The data obtained in the standing position are presented in Table 5 In this Table are included results from an earlier investigation The relation between body weight above the level measured (W) and the total load P on the disc in the standing position has not previously been mathematically expressed In conformity with eq (1) this can be written

(3) $$P_{standing} = P \sim k\ W$$

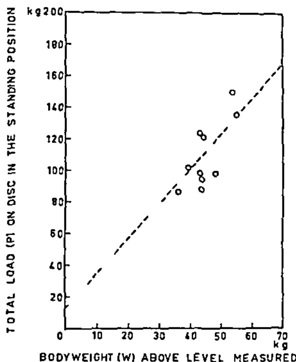



*Fig 4*

Relation between total load (P) on normal lumbar disc and calculated part of body weight above that level (W) in the standing position (Table 5)

TABLE 6

*Values for k Derived from Table 5 According to the Equation*

$P_{standing} = P_0 + k \cdot W$

| Case no | $k_s \left(= \frac{P-15}{W}\right)$ | Case no | $k \left(= \frac{P-15}{W}\right)$ |
|---|---|---|---|
| 8 | 2.27 | 19 | 2.55 |
| 15 | 1.74 | 1 | 2.51 |
| 16 | 2.39 | 2 | 1.81 |
| 17 | 1.69 | 6 | 2.18 |
| 18 | 1.96 | 8 | 1.90 |

Mean 2.1

In the sitting position $P_0$ was 30 kg *Akerblom* (1949) has shown that in this position the lumbar spine is flexed 30–40 degrees as compared to the standing position The intrinsic pressure of such a flexed lumbar disc was found to be 1.5 kg/cm² or more (*Nachemson 1962*

1963) In the straight spine of the standing position an intrinsic pressure of about 0 7 kg/cm was found

The value for $P_0$ in standing would be around 15 kg Using the values in Table 5 obtained from measurements of the intradiscal pressure in the third or fourth lumbar disc in the standing position in 10 individuals the constant k averaged 2 1 (1 7–2 5) Table 6 Fig 4

As was observed in the sitting position the values of $P_{standing}$ are higher than would be expected if gravitational and muscular forces from the erector trunci group alone were responsible for the load on the discs in this position Also in most subjects electromyographic studies of the sacro spinalis muscle group have revealed none or very weak action in this position (*Floyd & Silver* 1955 *Portnoy & Morin* 1956 *Morris et al* 1962) *Asmussen & Klausen* (1962) in a group of 100 schoolboys found some action potentials in 75 per cent of their material and from the findings they concluded that the line of gravity must pass in front of the lumbar vertebral column by about 1 to 2 cm

In comparison with the results obtained in the sitting position greater variations are found in the standing position (Figs 3 and 4) One reason for this could be that the same standing position is more difficult to maintain for a longer period of time (*Boman & Jalavisto* 1953)

The few data presented in Table 3 can be treated as was shown on page 321

(4) $$P_{standing} = P_0 + k\,W + k_3 \sin\alpha$$

Solving for $k_3$ will give the following values 3 8 3 7 (case no 6) 3 4 3 3 3 7 (case no 8) mean 3 6

The mean values of the constants in eq (4) obtained from the present material

$$P_0 = 15 \text{ kg}$$
$$k = 2\,1$$
$$k_3 = 3\,6$$

SUMMARY

The effect of forward leaning of 10 and 20 degrees on the intradiscal pressure in the sitting position was measured in eight individuals In addition in six of the patients the increase resulting from holding 10 and 20 kg weights in the hands was noted In two patients the same investigations were made in the standing position as well

Forward leaning of 20 degrees resulted in an increased intradiscal pressure and in an increased load on the disc. The increase averaged 30 per cent. Values between 13 and 18 kg/cm² were recorded, which implies that the third or fourth lumbar disc has to carry a load of 180 to 230 kg in this position. When carrying weights of 10 kg in each hand the load on these discs was between 260 and 340 kg.

In the standing position the increase of the disc pressure seemed to be proportionally of the same magnitude. The maximal value recorded in the forward leaning position of 20 degrees and carrying 10 kg in each hand was 19.7 kg/cm², corresponding to a load of 280 kg.

From these results it is possible to give relationships between the total load on the disc on one hand, and the position and the body weight above the disc measured on the other hand. The increase in pressure (and load) that occurs on forward leaning is approximately proportional both to sine for the angle of forward leaning and to the total weight above the level measured.

## RÉSUMÉ

L'effet du penchement en avant de 10 et de 20 degrés sur la pression intradiscale en position assise a été mesuré chez 8 individus. De plus, chez six des malades on a noté le résultat du port dans les mains d'un poids de 10 et de 20 kg. Chez deux malades ces investigations ont été pratiquées également en position debout.

Le penchement en avant de 20 degrés provoque une pression intradiscale accrue et une charge accrue sur les disques. La moyenne de l'augmentation est de 30 pour cent. Des valeurs entre 13 et 18 kg/cm² ont été enregistrées, ce qui signifie que le 3ème ou 4ème disque lombaire doit porter un poids de 180 à 230 kg dans cette position. Lorsqu'il est porté des poids de 10 kg dans chaque main la charge sur les disques est entre 260 et 340 kg.

En position verticale l'élévation de la pression sur le disque semble être *proportionnellement de la même grandeur*. *La valeur* maximum enregistrée dans la position penchée en avant de 20 degrés et le port de 10 kg dans chaque main a été de 19.7 kg/cm², correspondant à une charge de 280 kg.

De ces résultats il est possible d'établir un rapport entre la charge totale sur le disque d'un côté, et la position et le poids du corps au dessus du disque mesuré de l'autre côté. L'augmentation de la pression (et de la charge) qui se produit dans la position penchée en avant est

a peu pres proportionnelle a la fois au sinus de l angle du penchement en avant et au poids total au dessus du niveau mesure

## ZUSAMMENFASSUNG

Die Wirkung eines 10 und 20 gradigen Vorwärtslehnens in sitzender Stellung auf den intradiskalen Druck wurde an acht Personen gemessen Zusatzlich wurde bei sechs der Patienten die Druckzunahme die entstand wenn sie 10 bis 20 kg Gewicht in den Handen hielten beobachtet Bei zwei Patienten wurden die gleichen Untersuchungen auch in stehender Stellung vorgenommen

Vorwärtslehnen von 20 Graden ergab eine Zunahme des intradiskalen Druckes und eine starkere Belastung der Zwischenwirbelscheibe Die Zunahme betrug durchschnittlich 30 Prozent Werte zwischen 13 bis 18 kg Cm wurden aufgezeichnet Das bedeutet dass die dritte und vierte Lendenscheibe eine Last von 180 bis 230 kg in dieser Stellung zu tragen hat Wenn 10 kg Gewichte in jeder Hand getragen wurden war die Belastung dieser Scheiben zwischen 2?0 bis 340 kg

In stehender Stellung schien die Zunahme des Scheibendruckes proportional von derselben Grosse zu sein Der grosste aufgezeichnete Wert bei einer nachvorwärts lehnenden Stellung von 20 Graden und einem Gewicht von 10 kg in jeder Hand war 19 7 kg Cm was einer Belastung von 280 kg entspricht

Gemäss dieser Ergebnisse ist es moglich die Beziehungen einerseits zwischen totaler Belastung der Zwischenscheibe und andererseits Korperhaltung und Körpergewicht oberhalb der Scheibe anzugeben Die Druck (und Belastungs) zunahme die beim Vorwartslehnen entsteht ist ungefahr proportional sowohl der Grosse des Winkels beim Vorwartsbeugen als auch dem Gesamtgewicht uber dem gemssenen Niveau

## ACKNOWLEDGEMENTS

The author is indebte l to p fessor *B Brob rg* Divi ion of Strenth of Materials Lund In titute of T hn l g Sw den for valu ble aid in the technical presentation

Thi investigati n was upp rte l by a gr nt from the Konung Gustaf V s 80 *årsfond* Stockh lm

## REFERENCES

*Asmussen E* C *Klaus n K* Form n l Fun tion of th Erect Human Spine Clin Orth i 5 55 63 1962

*Bart link D L* The Role f Ab l m nal Pre u e in Reli ving the Pressure of the Lumbar Intervertebral D sc *J Bone Jt Surg 39 B* 18 ? 19 7

*Boman K & Jalavisto F* Standing Steadiness in Old and Young Persons Ann. Med exp Biol Fenn 31 447–455 1953

*Bradford F K & Spurling R C* The Intervertebral Disc Springfield Ill 1947

*Davis P R* Posture of the Trunk During the Lifting of Weights Brit med J 1 87–89 1959

*Eie N & Wehn P* Measurements of the Intra Abdominal Pressure in Relation to Weight Bearing of the Lumbosacral Spine J of the Oslo City Hospitals 12 205–217 1962

*Floyd W F & Silver P H S* The Function of the Erector Spinae Muscles in Certain Movements and Postures in Man J Physiol 129 184–203 1955

*Mattiash H H* Arbeitshaltung und Bandscheibenbelastung Arch orthop Unfall Chir 48 147–153 1956

*Morris J M Benner G & Lucas D B* An Electromyographic Study of the Intrinsic Muscles of the Back in Man J Anat 96 509–520 1962

*Morris J M Lucas D B & Bresler B* The Role of the Trunk in Stability of the Spine J Bone Jt Surg 43 A 327–351 1961

*Nachemson A* Lumbar Intradiscal Pressure Experimental Studies on Post Mortem Material Acta orthop Scandinav Suppl 43 1960

*Nachemson A* Some Mechanical Properties of the Lumbar Intervertebral Discs Bull Hosp Jt Dis 23 130–143 1962

*Nachemson A* The Influence of Spinal Movements on the Lumbar Intradiscal Pressure and on the Tensile Stresses in the Annulus Fibrosus Acta orthop scandinav 33 183–207 1963

*Nachemson A & Morris J* Lumbar Discometry Lumbar Intradiscal Pressure Measurements *in vivo* Lancet 1 1140–1142 1963

*Nachemson A & Morris J* *In vivo* Measurements of Intradiscal Pressure Discometry a Method for the Determination of Pressure in the Lower Discs J Bone Jt Surg 46–A 1077–1092 1964

*Perey O* Fracture of the Vertebral End Plate in the Lumbar Spine An Experimental Biomechanical Investigation Acta orthop Scandinav Suppl 25 1957

*Portnoy H & Morin F* Electromyographic Study of Postural Muscles in Various Positions and Movements Amer J Physiol 186 122–126 1956

*Ruff S* Brief Acceleration Less than one second In German Aviation Medicine World War II Washington D C U S Government Printing Office 1950 Vol I pp 584–597

*Schobert H* Sitzhaltung Sitzschaden Sitzmobel Springer Verlag Berlin 1962

*Waris W* Lumbar Disc Herniation Acta chir Scandinav Suppl 140 1948

*Akerblom B* Standing and Sitting Posture AB Nordiska Bokhandeln Stockholm 1949

Acta orthop Scandinav XXXV 329-337 1965

From the Orthopaedic Clinic of Karolinska Institutet Stockholm Sweden
(Head Professor S Friberg)

# ON VASCULAR INJURY IN LUMBAR DISC SURGERY

*By*

ULF NILSONNE and ANDERS HAKELIUS

In operations on prolapsed intervertebral discs in the lumbar region attention is usually concentrated primarily on the visible operation field Thus nerve roots and the spinal dura are treated with the utmost care and efforts are made to avoid lesion of the vessels of the vertebral canal The removal of the interior parts of the disc takes place however out of sight and the location of the instrument in the disc cannot be observed Less thought is given to the vulnerable structures in the form of the major vessels that pass immediately anterior to the disc

What then is the anatomical setting for vascular damage? The abdominal aorta lies directly to the left of the mid line on the upper four lumbar vertebrae It divides in 75 per cent of cases at the lower border of L 4 or at the disc between L 4 and L 5 reportedly more distally in women than in men (7) From the bifurcation the common iliac arteries pass the promontory and divide at the proximal sacroiliac joint into the internal and external iliac branches The vena cava runs immediately to the right of the aorta The junction of the common iliac veins is directly distal and to the right of the aorta bifurcation consequently as a rule at the upper border of L 5 or at the disc between L 4 and L 5 Immediately anterior to the junction runs the right common iliac artery The anterior aspect of the vertebral bodies is largely covered by the strong anterior longitudinal ligament which attaches more firmly to the vertebral bodies than to the discs Sagittally L 5 measures approx 3.5 cm and each of the lumbar bodies is a few millimetres smaller than the one below it (8)

We have confirmed these anatomical relationships by studies on cadavers It is easy to observe (Figs 1 and 2) that the discs L 3-L 4 and in particular L 4-L 5 are in close relationship to the great vessels The disc L 5-S 1 is not related to nearly the same extent




*Fig 1*

Cadaver specimen
The relations between the great vessels and lumbar discs
The metal pins mark the disc L 4–L 5 V = V cava A = Aorta




*Fig 2*

Cadaver specimen
The conchotome in the disc L 4–L 5
The aorta is visible to the left
A = Aorta
L IV, L V = vertebral bodies

Another striking observation was that the vessels, contrary to the information in current literature, were moderately free in relation to the front of the spine. The region between the vessels and the vertebral bodies with their discs was found to consist of a thin layer of loose fat and connective tissue which did not afford any rigid fixation. It is possible that the vessels are less free under physiological pressure conditions.

If an instrument perforates the anterior wall of the disc there is therefore an imminent risk of damage to the major vessels. A careful search through the literature does not give a clear picture of how frequently such injury occurs. The first case was published by *Linton* & *White* (1945), *i e* after about 10 years of lumbar disc surgery. This time lag may be connected with the fact that at first only the prolapsed portion was removed while later the operation was extended to include removal also of interior parts of the disc.

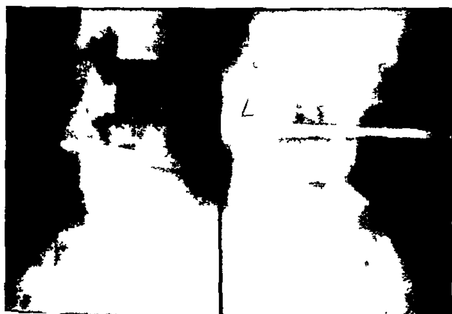



*Fig 3*

*X-ray during surgery. The conchotome is in the disc L 4–L 5 (left), L 3–L 4 (right).*

Several major surveys have subsequently been published on injuries of the major vessels in lumbar disc surgery, e.g. by *Harbison* (1954) 25 cases, *De Saussure* (1959) 106 cases, and *Hohf* (1963) 59 cases. These reports are based on questionnaires sent by the authors to American orthopedic surgeons and neurosurgeons. The sources are not fully documented, however, and there is probably a certain amount of duplication between the reports. At all events, even a cautious assessment gives at least 106 cases of injuries to the great vessels in lumbar disc surgery in the U.S.A. In addition, there are several reports of a minor amount of cases from other parts of the world. The injuries described include damage to single vessels as well as the formation of arterio-venous fistulas (1, 3, 5, 10, 11, 12, 15, 17, 18).

The majority of injuries occurred in operations on the disc L 4–L 5 (6, 9, 16), but cases exist of injury at all the levels in question. As a rule it was the common iliac artery which was damaged, less often the vena cava, the aorta, or the external and internal iliac arteries. Arterial injuries are thus well in the majority. Considering that the veins should be equally liable to injury, it seems likely that many venous haematomas have escaped clinical registration.



*Fig 4*
X ray during surgery lateral projection
The conchotome in the disc L4 L5 the aorta filled with contrast

Several reports draw attention to how easily vascular injury can happen In one case the complication arose just as the surgeon was warning his assistants about it (10) On the other hand it is striking that in about 50 per cent of the cases the injury did not in fact show up in the form of visible bleeding during the operation (6) Even when only a single vessel was involved the operation could be completed without anything unusual being noticed Instead the symptoms first appeared as post operative shock the correct diagnosis often came too late and as a result the mortality in this group was at least 50 per cent (6) In the case of arterio-venous fistulas the symptoms appeared weeks or months later and the mortality was considerably lower In one case the fistula was diagnosed 7 years after the operation (11) Most of these cases were reported by vascular surgeons exemplifying reconstructive vascular surgery

It would seem that most lumbar disc operations are done with the patient in the prone position During removal of the disc content the



*Fig 5*
X ray during surgery lateral projection
The conchotome in the disc L4–L5 the vena cava filled with contrast
(The bulge in the vessel is not caused by the instrument
but corresponds to the confluence)

lumbar spine is kept as kyphotic as possible Such factors may well affect the anatomical picture We have therefore tried to document the actual situation during an operation with the help of anatomical X ray studies

Fig 3 shows the position of the conchotome after a typical operation for prolapsed disc No attempt has been made to penetrate the depths of the disc, the picture simply illustrates routine procedure It is clear that the point of the instrument is very close to the anterior ligament

These somewhat startling pictures led to some angiographic studies during operations for herniated lumbar discs Plastic catheters were introduced percutaneously into the femoral artery and vein and led up into the abdominal aorta and the vena cava respectively The relative positions of the vessels could then be observed after giving a contrast injection [1]

[1] The late professor *Knut Lindblom* Head of the X ray Department, K[illegible] [illegible] sjukhuset gave us kind and valuable help in performing this part of the



*Fig 6*
X ray during surgery frontal projection
The conchotome in the disc L 5 S 1 (arrow)

In Figs 4 and 5 which exemplify the anatomical situation as seen in lateral X rays the conchotome is in the disc L 4–L 5 In Fig 4 the aorta is filled with contrast in Fig 5 the vena cava In both cases it is clear that the forward part of the instrument is extremely close to the great vessels In evacuation of the disc L 5–S 1 contrast filling of the aorta (Fig 6) shows that there is not so much danger of the vessel being damaged at this level the common iliac vessels run away laterally from the disc

## DISCUSSION

Clearly then anatomical conditions do exist for damage to the major vessels in surgery of the lumbar discs Of the discs usually involved in prolapse cases the risk is greater to the disc L 4–L 5 since here the vessels form a wide belt The arrangement of the vessels is such that the danger is considerably less at the level of L 5–S 1 At higher levels it is mainly the aorta which is liable to damage

Considering the large number of disc operations performed it is surprising that so few cases of damage to the vessels have been described There must obviously be other factors besides the actual anatomy which help to create such complications It is possible for instance that the surgeon uses too much force in penetrating the depths of the disc though in studies on cadavers we have found that the force required for the conchotome to perforate the anterior wall of the disc is considerably in excess of that usually used in disc removal This is also in agreement with *Friberg* (1954) who found that in the lower lumbar discs the degenerative process was most marked in the posterior part of the discs In the upper lumbar discs however the disintegration was more evenly distributed

Another possibility is that the disc has some anterior defect *Cloward* (1952) has described a case where a large anterior protrusion of the disc could be observed in preoperative discography At operation it was found that the prolapsed disc had caused depressions on the anterior longitudinal ligament and worn this thin *Lindblom* too has reported that in rare cases the contrast medium has leaked anteriorly in discography During anatomical X ray studies we were able to establish that the ability of the conchotome to penetrate the depths of the disc was a function of the degeneration in the disc when large complete sections had been removed the instrument sank easily down to the anterior wall when minor prolapses were evacuated the anterior part of the disc formed a protective barrier This has reinforced our opinion that a defect or at least weakness in the anterior part of the disc is a prerequisite for the conchotome reaching and perforating the major vessels

The instrumental technique for the removal of the disc may also be important Many surgeons scoop out the contents of the disc and warn against the use of biting instruments of the conchotome type (6 16) However if the disc does happen to be perforated the scoop type is just as likely to damage the vessels as the conchotome type Personally we simply warn against the use of long chonchotomes

Finally it should be emphasised that the symptoms of any vascular injury will not necessarily appear during the operation Close postoperative supervision of patients operated for prolapsed disc is therefore imperative in order that vascular surgery may be performed without delay should the need arise

## SUMMARY

A short survey is given of the literature of cases of injury to the great vessels in lumbar disc surgery. The authors give their anatomical findings from an investigation in the relationships between the vessels and the ventral aspect of the lumbar discs. These findings are derived in part from angiography during surgery for prolapsed discs. There follows a discussion of the various circumstances leading to vascular injury in this context.

## RESUME

Il est donne un compte rendu succinct de la litterature sur les cas de lesion des grands vaisseaux dans la chirurgie du disque lombaire. Les auteurs presentent les trouvailles anatomiques d'une enquete sur les rapports entre les vaisseaux et l'aspect ventral des disques lombaires. Ces trouvailles proviennent en partie de l'angiographie pratiquee durant l'operation pour la hernie discale. Suit une discussion des differentes circonstances donnant lieu à une lesion vasculaire dans ce contexte.

## ZUSAMMENFASSUNG

Eine kurze Übersicht der Literatur bezuglich Fallen von Beschadigung der grossen Gefässe anlässlich lumbaler Zwischenwirbelscheibenchirurgie wird gegeben. Die Verfasser zeigen ihre anatomischen Befunde im Zusammenhang mit einer Untersuchung der Beziehungen zwischen den Gefassen und der ventralen Oberflache der Lendenwirbelscheiben. Diese Befunde wurden teilweise mittels Angiographie wahrend des chirurgischen Eingriffes wegen prolabierten Scheiben erhalten. Eine Besprechung der verschiedenen Umstände die in diesem Zusammenhang zur Gefässbeschädigung fuhren folgt.


## REFERENCES


1. *de Bakey M E, Cooley D A, Morris J r G C & Collins H*: Arterio Venous Fistula Involving the Abdominal Aorta. Ann Surg *147* 646 1958.
2. *Clouard R G*: Anterior Herniation of a Ruptured Lumbar Intervertebral Disc. Arch Surg *64* 457 1952.
3. *Fortune C*: Arterio Venous Fistula of the Left Common Iliac Artery and Vein. Med J Aust *1* 660 1956.
4. *Friberg S*: Lumbar Disc Degeneration in the Problem of Lumbago Sciatica. Bull Hosp Jt Dis XV 1 1954.

5 *Glass B A & Ilgenfrit H C* Arterio Venous Fistula Secondary to Operation for Ruptured Intervertebral Disc Ann Surg *140* 1?? 1954
6 *Harbison P S* Major Vascular Complications of Intervertebral Disc Surgery Ann Surg *140* 342 1954
7 *Heidsieck E* Zur Skeletotopie der grossen Aste der Bauchaorta Anat Anz *66* 6 1928–29
8 *Henle cit Rauber Kopsch* Lehrbuch und Atlas der Anatomie des Menschen G Thieme Leipzig 1940
9 *Hohf R P* Arterial Injuries During Orthopedic Operations Clin Orthop 28 21 1963
10 *Holscher F C* Vascular Complications of Disc Surgery J Bone Jt Surg *30–A* 968 1948
11 *Horton R E* Arterio Venous Fistula Following Operation for Prolapsed Intervertebral Disc Brit J Surg 49 77 1961–62
12 *Leavens M E & Bradford F K* Ruptured Intervertebral Disc Report of a Case with a Defect in the Anterior Annulus Fibrosus J Neurosurg *10* 544 1953
13 *Linton R R & White P D* Arterio Venous Fistula between Right Common Iliac Artery and the Inferior Vena Cava Arch Surg *50* 6 1945
14 *Lindblom K* Personal Communication
15 *Mack J R* Major Vascular Injuries Incident to Intervertebral Disc Surgery Amer Surg 92 752 1956
16 *de Saussure R L* Vascular Injury Coincident to Disc Surgery J Neurosurg *16* 222 1959
17 *Seely S F Hughes C W & Jahnke Jr F J* Major Vascular Damage in Lumbar Disc Operation Surg 35 421 1954
18 *Smith V M Hughes C W Sapp O Jay R J & Mattingly T W* High Output Circulatory Failure Due to Arteri Venous Fistula Arch intern Med *100* 833 1957

Acta orthop Scandinav XXXV 338-347 1965

From Department of Pediatrics County Hospital Alesund Norway
(Chief of Service Dr A Drablos M D )
and Sophies Minde Ortopedic Hospital Oslo Norway
(Head Prof dr med Ivar Alvik)

# FOLLOW UP STUDY OF HIP JOINT DYSPLASIA TREATED FROM THE NEWBORN STAGE

*By*

INGULF MEDBØ

In a previous paper I described the management of 50 babies with hip joint dysplasia (hd) treated primarily with a Frejka *pillow splint* These children were followed up to a stage where in my opinion their hip joints showed normal development At that time none had clinical signs of hd

Hip joint dysplasia in this connection means cases with luxation and subluxation as well as cases with a defective development of the hip joint without dislocation

The X rays for a routine examination would have been regarded as normal However on a meticulous geometrical examination of the X rays I was in some doubt and divided the results into the following subgroups

| | |
|---|---|
| (1) Normal hips | *24 children* |
| (2) Normal? hip | 14 children |
| (3) Dysplastic? hips | 10 children |
| (4) Dysplastic hips | 1 child |
| Not fully followed up | 1 child |

In the literature there is little general agreement as to the radiological appearance of the normal hip joint in young children There are several methods of measuring the hip joints in an A-P view of the pelvis using different accessory lines In practice most of these methods are difficult to apply and the placement of the accessory lines seems inexact

*Wiberg* describes a method of evaluation of the X ray appearance of the hip joint in young individuals based on the center edge (CE) angle In my opinion this method is suitable for practical use Furthermore *Severin* has—in his monograph—given a description of the normal hip joint in children at the age of 6 years according to this method

*Massie & Howorth* have shown that the same limits of the CE angle are valid down to the age of 3 years

Because of my own doubts as to the radiological result of the treatment with a Frejka splint I have felt it desirable to do a follow up examination of these 50 cases as the children now have reached the age of 5–7 years and the radiological appearance of their hip joints should be comparable to the normal series of Severin

## METHOD OF FOLLOW UP EXAMINATION

Each of the children was accompanied to the examination by one of the parents

1) The mother or father was questioned thoroughly as to symptoms of hip disorders or of disorders of the lower extremities
2) A clinical examination of the lower extremities was performed Great emphasies was put on the range of rotational movements of the hip joint in order to detect any clinical signs of anteversion of the neck of the femur
3) Two X rays were taken of each child
   a A P view of pelvis with both femurs in neutral rotation
   b A P view of pelvis with both femurs in maximal internal rotation

The combination of these two X rays will give an impression of the anteversion but definitely no accurate measurements of the same

Of the 50 patients 48 had a complete examination as described above One was clinically examined but no X rays were taken and one child did not come to the examination because of mental instability Therefore the result of clinical examination refer to 49 children and the roentgenological part to 48 children

## FINDINGS AT FOLLOW UP EXAMINATION

### *Symptoms*

None of the children had any symptoms of previous hip joint dysplasia Their parents assured me that none was physically handicapped in comparison to other children of the same age and sex None had found reason to see a doctor because of the lower extremities after the treatment was ended

*Signs*

The Trendelenburg sign was negative in all children No inequality in leg length was observed judging by the pelvic position when standing No muscular atrophy of the lower extremities was found 10 children had increased valgus position of the knees most likely a physiological valgus in relation to age and sex Definite planovalgus of the feet was found in 2 children aplanation of the foot without valgus of the heel was found in 3 children

Of other pathological conditions concerning the musculo-skeletal system one was noted an asymmetric funnel deformity of the thorax

The gait was observed and the parents were asked about certain abnormalities *in gait The conclusion was that one child (TH)* walked with definite intoeing 4 children had a slight degree of intoeing None was in any way incapacitated because of this in walking or running

The passive range of motion of the hip joints was measured as exactly as possible

The flexion abduction and adduction were measured in supine position and the extension internal and external rotation were measured in prone position

The upper and lower margins of the different excursions were found to be

| | |
|---|---|
| Flexion | 160–130 |
| Extension | 35–20 |
| Abduction | 80–40 |
| Adduction | 40–35 |

The rotational excursions are shown graphically in Fig 1

The curves show that the average total rotation is 97 with an average internal rotation of 62 and external rotation of 35 which most likely is normal for this age group In no case did the excursion of rotation differ more than 10 from rt to lt hip

The total range of rotation which in none of the children exceeds 120 does not indicate laxity of the hip joints

It is generally accepted that an internal rotation exceeding 70 is indicative of increased anteversion of the neck of the femur

In this series an internal rotation of 70–80 is found in 7 hips in 4 patients In 2 of these there was observed intoeing when walking but the other 2 showed no signs of this walking habit In none of these 4 cases did the intoeing give subjective symptoms such as frequent stumbling *fatigue or muscular pain in the lower extremities*

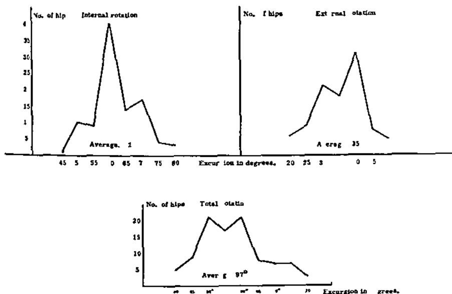



*Fig 1*
The passive rotation of 98 hip joints measured in prone position

*Roentgenological Examination*

As mentioned previously there is little general agreement as to the X ray appearance of the normal hip joint in children of this age group

I have chosen to use the method of *Wiberg* with *Severin*s correction for younger children The CE angles of the 96 hips are shown in Table 1 in relation to the normal values of *Severin*

According to this table the distribution of the CE angle is practically identical in the two series up to 25 Above this level there is some difference but not more than expected in two groups of this size

In this series of 50 children with hd the result of treatment so far is that the roentgenological appearance is within normal limits I think that this is to regard the problem too easily or optimistically

*Severin* says in his monograph that a hip joint with a CE angle 20 or more is definitely normal in a 6 year old child CE angles below 15 are definitely pathological CE angles between 15 and 20 are uncertain

In this series there are 2 hips in different children with a CE angle less than 20 The CE angles in these are as follows

| | | |
|---|---|---|
| Case SMA | Rt hip 16 | Lt hip 20 |
| Case HMY | Rt hip 15 | Lt hip 24 |

TABLE 1

*The CE Angle of 96 Hip Joints Compared with Normal Values*

| CE angle | Normal values (Severin) age 6-13 yrs | | This series Age 5- yrs | |
|---|---|---|---|---|
| | No of hips | | No of hips | |
| 15 | 1 | 2 | 1 | 2.1 |
| 16 | – | | 1 | |
| 17 | 1 | | – | |
| 18 | 1 | | – | |
| 19 | – | | – | |
| 20 | 8 | 34½ | 3 | 34.3 |
| 21 | 5 | | 6 | |
| 22 | 6 | | 5 | |
| 23 | 7 | | 4 | |
| 24 | 9 | | 6 | |
| 25 | 12 | | 9 | |
| 26-30 | 42 | 31 | 34 | 35.4 |
| 31-35 | 38 | 28 | 19 | 19.8 |
| 36-40 | 6 | 4½ | 5 | 5.3 |
| 41-45 | – | | 2 | 2.1 |
| 46 | – | | 1 | 1.0 |

In only one additional case I have found a marked difference of CE angle from rt to lt hip case GF rt hip 28 lt hip 41

The only patient who had a definite dysplasia in one hip (rt ) when treatment was finished at the age of 2 years 6 months (case TH) had at follow up a CE angle of 20 (rt ) and 25 (lt )

## DISCUSSION

Symptoms No child is suffering any sequelae of his previous hip joint dysplasia

Signs The follow up showed very few signs of a previous hip joint dysplasia

In one case (TH) there was marked intoeing when walking The range of rotation was

| | | |
|---|---|---|
| Internal | 65 -70 | (rt -lt ) |
| External | 20 -20 | (rt -lt ) |

In 4 cases there was found a slight intoeing when walking This walking habit however did not seem necessarily to be related to an

increased internal rotation of the hip joint and was no handicap in walking or running.

Upon clinical examination no other sequel of previous hip joint dysplasia was found. The few cases of flat feet are not uncommon in a group of children of this type and the valgus position of the knees observed in 10 cases is as mentioned most likely physiological in this age group.

*Roentgenological Signs*

Judged by the CE angle the whole group is within the normal limits established for this method of evaluation of hip joints.

The few cases mentioned with regard to marked difference in CE angle from rt. to lt. hip or with regard to abnormality of hip joint by general appearance need further comment.

In one of the cases there was at the time of follow up definite signs of a healed avascular necrosis of the head of the femur on one side. This necrosis most likely had taken place when weightbearing started but had presented such slight symptoms that neither the child nor the parents had noticed them. (Case SMA)

In the rest of the cases I can find no reason for the difference in CE angle from rt. to lt. hip and feel that all the joints must be within the normal limits of variation.

In view of these cases I feel that *Severin* was right in establishing an uncertain lower limit for the CE angle in children of this age.

*Previous Reading of X-rays*

In my first paper based on the standard of the hips in these 50 children at the close of treatment most often when the child was about 1 year old I was uncertain of my X-ray readings.

I divided the hips in four groups.

(1) "Normal"
(2) "Normal?"
(3) "Dysplastic?"
(4) "Dysplastic"

By reviewing X-rays of the hips of these children at the age of 5-7 years I could have relieved any doubt. The follow up shows that 22 children in group "Normal" have an average CE angle of 28½° 14 children in group "Normal?" have an average CE angle of 26½° and 10 children in group "Dysplastic?" have an average CE angle of 2[illegible]

a

b







c

*Fig 2 Case LS*

a Age 5 days Ortolani s sign positive bi laterally

b Age 9 mths Treatment finished Rated Normal hips

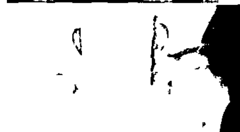
c Age 5 years CE angles Rt 21 Lt 24

a

b







c

*Fig 3 Case LR*

a Age 3 days Ortolani s sign positive bilaterally

b Age 10 mths Treatment finished Rated "Normal? hips

c Age 5 years 3 mths CE angles Rt 29 Lt 22

In the single case where a dysplastic rt hip was diagnosed at the close of treatment I still find the same hip joint dysplastic with CE angle 20

The follow up thus shows that all the doubtful cases have shown normal development with a single exception

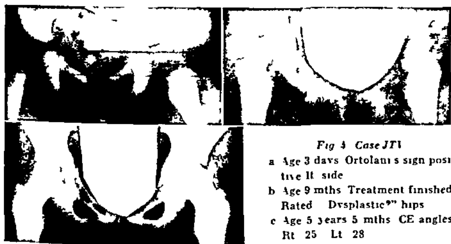



*Fig 4 Case JTV*
a Age 3 days Ortolani's sign positive lt side
b Age 9 mths Treatment finished Rated "Dysplastic?" hips
c Age 5 years 5 mths CE angles Rt 25 Lt 28

## ROENTGENOLOGICAL SIGNS OF INCREASED ANTEVERSION

The clinical examination shows a few cases with a trend of gait indicating increased anteversion of the neck of the femur The examination for rotational movement of the hip joints also reveals few cases with an internal rotation of the hip joints indicating the same dysplastic sign However some of the children with intoeing have a normal range of rotational movement and some of the children with increased passive internal rotation have a completely normal gait

Roentgenological examination of the hip joints in these cases does not give any definite impression of increased anteversion of the neck of the femur nor of a better position of the head in the acetabulum in an internally rotated than in a neutral position I therefore feel that a rotational osteotomy of the femur should be performed only in cases where clinical examination shows a marked intoeing gait with clumsiness in walking and running or where the X ray examination reveals a definite improvement of the position of the femoral head in relation to the acetabulum with internal rotation of the hip joints

## SUMMARY AND CONCLUSIONS

50 children with clinical and roentgenological signs of hipjoint dislocation or dysplasia were treated from the newborn stage with

Frejka pillow splint. Active treatment was in most cases finished at the end of the first year of life.

*49 of the children were reexamined at an age of 5 to 7 years.* Based on the findings at the reexamination following conclusions were reached:

1. A correctly treated hipjoint dislocation or dysplasia in the new born stage leads to development of perfectly normal hipjoints including normal anteversion of the femoral neck.

2. Even if the treatment is started in the newborn stage and the first year of life shows normal development of the hipjoints, a periodic follow up of these children should be performed in subsequent years. In this way one should be able to detect further signs of the disease and start the treatment at such an early stage that a deformity of the hip joint may be prevented.

## RÉSUMÉ ET CONCLUSIONS

50 enfants présentant des signes cliniques et radiologiques d'une dislocation ou displasie de l'articulation de la hanche ont été traités à partir de la naissance au moyen d'une coussin attelle Frejka. Le traitement actif a été achevé dans la plupart des cas à la fin de la première année d'âge.

49 de ces enfants ont été réexaminés entre 5 et 7 ans. En se basant sur les trouvailles de ces réexamens, les conclusions suivantes ont été tirées:

1. Une dislocation ou displasie de l'articulation de la hanche correctement traitée depuis la naissance mène au développement d'articulations de la hanche parfaitement normales y compris l'antéversion du col fémoral.

2. Même si le traitement est entrepris chez le nouveau né et qu'il y ait un développement normal des articulations de la hanche pendant la première année de vie, un examen périodique de ces enfants doit avoir lieu dans les années suivantes. De cette manière on a la possibilité de détecter de nouveaux signes de la maladie et d'entreprendre un traitement suffisamment tôt pour prévenir une déformation de l'articulation de la hanche.

## *ZUSAMMENFASSUNG UND SCHLUSSFOLGERUNGEN*

50 Kinder mit klinischen und röntgenologischen Zeichen einer Hüftverrenkung oder Dysplasie wurden seit der Geburt mit Frejkas Polster

schiene behandelt Die Aktive Behandlung war in den meisten Fällen am Ende des ersten Lebensjahres abgeschlossen 49 Kinder wurden im Alter von 5 bis 7 Jahren nachuntersucht Auf Grund der Befunde bei der Nachuntersuchung kommt man zu folgenden Schlussfolgerungen

1 Eine richtig behandelte Huftverrenkung oder Dysplasie beim Neugeborenen fuhrt zur Entwicklung einer vollkommen normalen Hufte mit normaler Anteversion des Schenkelhalses

2 Selbst wenn die Behandlung am Neugeborenen begonnen wird und die Hufte im ersten Lebensjahre eine normale Entwicklung zeigt sollte eine zeitweilige Nachuntersuchung dieser Kinder in den folgenden Jahren vorgenommen werden In dieser Weise sollte man im Stande sein weitere Zeichen der Erkrankung zu entdecken und mit der Behandlung zu einem so fruhen Zeitpunkt zu beginnen dass die Verbildung des Huftgelenkes verhindert werden kann

## REFERENCES

*Alvik I* Increased Anteversion of the Femur as the Only Manifestation of Dyspl of the Hip Clin Orthop No 22 p 16–20 J B Lippincott Co 1962

*Massie W K & Howorth M B* Cong Dislocation of Hip J Bone Jt Surg 32–A 519–531 1950

*Medbö I U* Early Diagnosis and Treatment of Hip Joint Dyspl Acta orth p Scandinav *31* 282–315 1961

*Severin E* Contribution to the knowledge of Cong Disloc of the Hip Joint Acta chir Scandinav *84* (Suppl 63) 1941

*Wiberg C* Studies on Dyspl Acetab and Cong Sublux of the Hip Joint Acta chir Scandinav *83* (Suppl 58) 1939

Acta orthop. Scandinav. XXXV 348–357 1965

From the Orthopaedic Clinic Härnösand
(Head: Nils Lindström M.D.)

# ARTHROPLASTY OF THE HIP ACCORDING TO THOMPSON AND MOORE

*By*

LARS DANIELSSON

## INTRODUCTION

The first attempt at arthroplasty of the hip was made by *Barton* in 1826. Later *Ollier* used muscle tissue, *Murphy*, fascia, and *Jones*, gold folio as a support between the femur and the pelvis until the introduction of the Smith Petersen vitallium cup in 1938. The advent of the Judet prosthesis marked the beginning of the wave of enthusiasm for arthroplasty during the last decade and paved the way for various endoprostheses designed by *d'Aubigné, Eicher, McBride, Moore, Thompson* and others.

Stainless steel and vitallium provided inert material for such appliances and particularly vitallium appears to possess the desirable qualities.

## MATERIAL

From 1953 to 1960 all together 32 patients underwent operation with insertion of Thompson or Moore prosthesis at the Orthopaedic Clinic, Härnösand. All the operations were unilateral. Of these 32 patients one has in the meantime died and one has moved to another part of the country. The material available for the present after-examination thus consisted of 30 patients (20 females and 10 males).

The patients' ages at the time of the operation ranged from 32 to 76 (average 59 years). The females were on the average somewhat older than the males.

The interval between the operation and the after-examination was on the average 3–4 years (range 1 to 7 years).

### *Indications for Surgery and Operative Technique*

The indications for operation were coxarthrosis in 16 cases, pseudoarthrosis of the femoral neck in 12 and necrosis of the femoral head in 2. Of the patients with coxarthrosis 6 had been treated previously with a Judet prosthesis that had loosened or broken.

The operation was peformed under spinal analgesia in 28 cases and under general anaesthesia in 2 A Smith Petersen incision was used in 17 cases and a Gibson Mc Farland incision in the remaining 13

Physiotherapy was started 2½ weeks after the operation with successively increasing weight bearing after 4 weeks

The patients spent on the average 12 weeks in hospital half of them less than 8

## RESULTS

The main purpose of the present investigation was to detect any complications and to assess functional activity mobility pain and post operative changes in the roentgen appearance of the hip Shepherd s schema was used in the estimation of functional activity and range of motion of the hip

### *Complications*

Operative or early postoperative complications had occurred in 11 cases (Table 1)

TABLE 1
*Postoperative Complications*

| | |
|---|---|
| Fracture | 3 |
| Tip of prosthesis through corticalis | 1 |
| Infection | 2 |
| Dislocation | 1 |
| Thrombosis | 4 |
| Total | 11 |

In 2 cases a fissure of the shaft had occurred on insertion of the prosthesis and in one case a supracondylar fracture on reposition of the prosthesis One of the fissures had not been noticed and the patient had been allowed to leave his bed before the fissure had healed This had resulted in bone resorption beneath the prosthesis and considerable slipping of the latter as well as in poor hip mobility and functional activity (Fig 1) *In the other 2 cases weight bearing had not been allowed* until the fissure and the fracture had healed This had made a longer stay in hospital necessary but later mobility and functional activity were excellent

In one case the tip of the prosthesis had been driven through the corticalis of the lateral aspect of the femur in which it had gradually sunk deeper and deeper (Fig 2) At the after examination the mobility



Fig 1 a



Fig 1 b

*Fig 1 a* Immediately after operation Fissure through lesser trochanter
*Fig 1 b* 4 years after operation Severe slipping of prosthesis

and functional activity proved excellent but there is surely a risk of spontaneous fracture or loosening of the prosthesis

Verified infection occurred in 2 cases In one of them the infection was refractory to antibiotic therapy and the prosthesis had to be removed 15 months after the operation A superficial wound infection (in the other patient) responded favourably to antibiotics and at the after examination mobility as well as functional activity was excellent

In one case dislocation of the prosthesis occurred immediately after operation and was afterwards removed

Thrombosis of the leg had been noted in 4 cases

### *Subjective Evaluation*

At the time of the after examination the prosthesis was already removed in 2 cases Of the remaining 28 patients 22 were satisfied or very satisfied indeed while 6 were less satisfied or dissatisfied



Fig 2



Fig 3

Fig 2 3½ years after operation Prosthesis now sunk deeper with further projection of tip through corticalis

Fig 3 3½ years after operation Prosthesis loose and broken

*Functional Activity*

Five of the 28 patients had returned to their previous work Three of them were women who did all the work in fairly large households one was a motor mechanic and the fifth was a farmer who did all the work except hay making on a small farm with 4 cows and who did a fair amount of skiing in his spare time during winter Eleven patients could only do light manual work such as cooking washing of dishes and light housework Twelve patients could not do work placing substantial demands on the hip

All of the patients could use the toilet without help Somewhat more than half could tie up their shoe laces themselves take a bath and walk more than 1 500 metres

Back pain and knee pain were rare

Atrophy of the thigh corresponding on the average to a decrease of one cm in the circumference of the limb and shortening of the leg on the average by one cm were noted

Most of the patients had a positive or questionable Trendelenburg

*test and walked with a limp. Only 2 of the patients walked without any detectable limp.*

In 22 of the cases functional activity was classified as excellent or good. The best result was found in the group necrosis of the femoral head—pseudarthrosis (Table *2*).

TABLE 2
*Functional Activity*

| | Necrosis of the femoral head pseudarthrosis | Coxarthrosis | Total |
|---|---|---|---|
| Excellent | 10 | 5 | 15 |
| Good | 1 | 6 | 7 |
| Fair | 1 | 3 | 4 |
| Bad | 1 | 1 | 2 |
| Total | 13 | 15 | 28 |

## *Mobility of the Hip*

The range of movement of the hip was good with the following average values: flexion extension 80, abduction—adduction 30° and total rotation 20. The values noted for the group necrosis of the femoral head—pseudarthrosis were better than those for the coxarthrosis group (Table 3). Flexion contracture was noted in more than half of the patients, especially in those with coxarthrosis.

TABLE 3
*Mobility of the Hip*

| | Necrosis of the femoral head pseudarthrosis | Coxarthrosis | Total |
|---|---|---|---|
| Excellent | 11 | 6 | 17 |
| Good | 2 | 7 | 9 |
| Fair | 0 | 2 | 2 |
| Bad | 0 | 0 | 0 |
| Total | 13 | 15 | 28 |

## *Hip Pain*

Starting pain and stiffness were most common among the patients with coxarthrosis. Four patients reported pain during rest and severe pain when walking. In all of these patients bone resorption was marked



F j 4



Fig 5

Fig 4 5½ year afte peration Severe lipping of pr the i subluxati n reactive new f rmat n f bone in femoral diaphysis

Fig 5 5 years after peration Pro the is l e and lipping d wn in fem ral di physis

the prosthesis had slipped and the greater trochanter abutted against the upper edge of the acetabulum Two of these prostheses were loose one was moreover partially dislocated and the fourth was even broken (Figs 3 4 and 5) Eight patients were absolutely free from pain

## Roentgenographic Appearance

Attempts were made to obtain exactly the same projections as at preceding examinations

Twenty prostheses had slipped down into the femoral diaphysis (Table 4 Such displacement was most common in those cases where prosthe s did not abut against the medial corticalis or the calcar femorale Three prostheses had not been driven in completely Two

of these which not even later abutted against the calcar femorale had continued to slip down in the diaphysis while the third which had afterwards abutted against the calcar femorale had not slipped further

Bone resorption and slipping of the prosthesis varied with the interval between the operation and the after examination (Table 5)

TABLE 4
*Slipping of Prosthesis Abutting and not Abutting the Calcar Femorale*

| | Slipping | No slipping | Total |
|---|---|---|---|
| Abutting | 5 | 7 | 12 |
| Not abutting | 15 | 1 | 16 |
| Total | 20 | 8 | 28 |

TABLE 5
*Slipping of Prosthesis within Different Intervals of Operation*

| Age of prosthesis | Average slipping |
|---|---|
| 1–2 years | 8 mm |
| 2–3 years | – |
| 3–4 years | 8 mm |
| 4–5 years | 12 mm |
| 5–6 years | 12 mm |
| 6–7 years | 23 mm |

The Moore prostheses tended to slip less than the Thompson prostheses the average distance being 2 mm for the former and 9 mm for the latter But the Moore prostheses had been worn for a shorter period (average 2–3 years) than the Thompson prostheses (average 3–4 years) The longest distance a prosthesis had slipped was 34 mm

Bone resorption in the acetabulum and so called acetabular migration were seen in almost half of the cases and were most common in the coxarthrosis group

Substantial calcification of the soft tissues was noted in 7 cases This *calcification was however not correlated with certainty* with previous operations indications for operation type of incision used or the interval between the operation and the after examination

Diffuse sclerosis was seen in the region of the lesser trochanter as well as at the tip of the prosthesis and especially lateral thereto In some cases a layer of sclerosis was seen along the shaft of the prosthesis

## DISCUSSION

The Moore and Thompson prostheses as well as the Judet prostheses and the cup arthroplasties give good early results. The end results obtained with the Judet prostheses and the cup arthroplasties did not come up to expectation. Will the end results of treatment with Thompson or Moore prostheses be better? Anything like a reliable answer to this question requires thorough after examinations and a very long follow up. *Thompson*'s review was based on 34 patients who had been operated upon 2½ years previously. *Moore*'s on 159 patients reviewed 2 to 6 years after operation and an American after examination by questionnaire covered more than 10 000 cases in which a period of 4 years on the average had elapsed since the operation. These authors reported operative and post operative complications but gave only scanty data about the condition of the patients at the review. The operative and post operative complications in the present material were roughly the same as in other series on record but the end results appeared to be less good.

Neither *Thompson* nor *Moore* mentioned bone resorption or slipping of the prosthesis. Yet these complications were common in the present material and were most often the cause of the poor long term results. Slipping was particularly common when the prosthesis did not abut against the medial corticalis or the calcar femorale possibly in combination with early and uncontrolled weight bearing.

In order to diminish the risk of bone resorption and slipping of the prosthesis the latter should primarily abut against the calcar femorale and the patient should use a stick for a long time possibly for the rest of his life.

## SUMMARY

Thirty patients were after examined clinically and roentgenologically 1–7 years after insertion of hip prosthesis. Bone resorption and slipping of the prosthesis proved common. Rarely could the patients return to heavy work but only few of them required assistance for their day to day existence.

## RÉSUMÉ

30 malades ont été réexaminés cliniquement et radiologiquement entre 1 et 7 ans après insertion d'une prothèse de la hanche. On a couramment constaté une résorption osseuse et un glissement de la prothèse. Les malades peuvent rarement reprendre un travail dur mais

tres peu d'entre eux ont besoin de secours pour assurer leur subsistance de tous les jours

## ZUSAMMENFASSUNG

Dreissig Patienten wurden 1–7 Jahre nach der Anbringung einer Hüftprothese klinisch und röntgenologisch nachuntersucht. Knochenresorption und Gleiten der Prothese erwies sich als ein gewöhnliches Ereignis. Nur selten konnte ein Patient schwere Arbeit wieder aufnehmen, aber nur wenige benötigten Hilfe für das tägliche Leben.

## REFERENCES

*Buxton, J. D. & Waugh, W.*: Radiographic Bone Changes at the Hip after Insertion of an Acrylic Prosthesis. J. Bone Jt Surg. *36-B*: 50, 1954.

*Collins, D. H.*: Tissue Changes in Human Femurs Containing Plastic Appliances. J. Bone Jt Surg. *36-B*: 458, 1954.

*Harty, M.*: The Calcar Femorale and the Femoral Neck. J. Bone Jt Surg. *39-A*: 625, 1957.

*Hinchey, J. J. & Day, P. L.*: Comparison of Judet and Intramedullary Type of Prosthesis in Nonunion of Hip Fractures. Sth. med. J. *48*: 1158, 1955.

*Hirsch, C.*: Acrylarthroplastik vid komplikationer efter collumfrakturer. Nord. Med. *51*: 475, 1954.

*Hirsch, C. & Brodetti, A.*: The Weight Bearing Capacity of Structural Elements in Femoral Necks. Acta orthop. Scandinav. *26*: 81, 1956.

*Hirsch, C.*: Thompson Moore Vitallium Prosthesis in Resection Recontruction of the Hip Joint. Acta orthop. Scandinav. *27*: 271, 1958.

*King, D. E., Straub, L. R. & Lambert, C. N.*: Final Report of the Committee for the Study of Femoral Head Prosthesis. J. Bone Jt Surg. *41-A*: 883, 1959.

*Laurent, L. E. & Stoula, A.*: Alloplastik vid hoftledsarthros. Nord. Med. *62*: 1679, 1959.

*Levy, L. J., Lipscomb, C. P. & McDonald, H. C.*: Complications of Judet Arthroplasty Due to Foreign Body Reaction to Nylon Prosthesis. J. Bone Jt Surg. *36-A*: 1175, 1954.

*Lindstrom, N.*: Arthroplasty and Arthrodesis in Arthrosis Deformans Coxae. Acta orthop. Scandinav. *21*: 124, 1951.

*Mayer, L.*: Orthopaedic Surgery in the United States of America (Arthroplasty). J. Bone Jt Surg. *32-B*: 502, 1950.

*Moore, A. T.*: The Self Locking Metal Hip Prosthesis. J. Bone Jt Surg. *39-A*: 811, 1957.

*Morin, R.*: Et kliniskt og experimentelt arbejde over hoftealloplastik som behandling overfor egnede tilfaelde af fractura colli femoris og specielt *følgetilstande herefter*. Munksgaard, Copenhagen 1957.

*Palmer, I.*: Den mediala collumfrakturens behandling på nytt aktuell. Nord. Med. *46*: 1700, 1951.

*Reynolds, F. C.*: Preliminary Report of the Committee of Fractures and Traumatic Surgery on the use of Prosthesis in the Treatment of Fresh Fractures of the Neck of the Femur. J. Bone Jt Surg. *40-A*: 877, 1958.

*Schwarzmann J R* Arthroplasty of the Hip in Rheumatoid Arthritis J Bone Jt Surg *41-A* 705 1959

*Shepherd M M* A Review of 650 Hip Arthroplasty Operation J Bone Jt Surg *36-B* 567 1954

*Shepherd M M* Assessment of Function after Arthroplasty of the Hip J Bone Jt Surg *36-B* 354 1954

*Smyth E H J* The Mechanical Problem of the Artificial Hip J Bone Jt Surg *40-B* 78 1958

*Stinchfield F E Cooperman B & Shea B* Replacement of the Femoral Head by Judet or Austin Moore Prosthesis J Bone Jt Surg 39-A 1043 1957

*Straub L R, King D E & Lambert C N* Symposium on Femoral Head Replacement Prosthesis J Bone Jt Surg *38-A* 407 1956

*Thompson F R* Two and a Half Years Experience with a Vitallium Intramedullary Hip Prosthesis J Bone Jt Surg *36-A* 489 1954

*Waring T L & Anderson L D* Crawford Adams Cup Arthroplasty J Bone Jt Surg *43-A* 431 1961